Astronomy

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Sky and TELESCOPE

Babylonian lunar tablet

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Whole Number 37
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In This Issue:

On Babylonian Lunar Theory
Progress Report at Cleveland
Color in the Sky
Air Almanacs
Making Your Own Telescope
Stars for November

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The Editors Note .

WE WERE amazed and proud to receive for publication a V-mail letter datelined "Germany, 18 September," written by Pfc. George Shenkar to Mrs. Margaret Back, secretary of the Detroit Astronomical Society:

"I received your postal card quite a while back, while I was still in France. After going across France and visiting Paris on the way, I have finally wound up across the borders of Hitler's Germany. Let's hope that my next letter may be headed Berlin. For the benefit of any members of the Detroit Astronomical Society who may have seen Paris, I want to say that it's as beautiful as ever, the people being just a bit worse from wear after 4½ years of German occupation.

"I just received my September issue of **Sky and Telescope** and haven't yet had a chance to start on it. I am very happy to maintain correspondence with you. Please say hello to the members for me. Thanks for the news about Mr. Vann."

Mrs. Back says that Marvin Vann is another Detroit member who was starting off for the tropics with a PT boat and expected to be in charge of an advanced base. He wrote her:

"I have a complete 6-inch optical system with me that I'm taking to the tropics so I'll be able to study the southern skies and maybe bring new joy to bored sailors there. . . . I don't know how many of us from the society are in service but I do know that now they realize how wonderful those little Sunday meetings were. I've been receiving your notices from the society and it's been fun getting them; just to know what's going on back there has meant much to me."

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COVER: One of the oldest known specimens of a lunar ephemeris. This reproduction of a Babylonian tablet is enlarged about 1½ times from an original photograph which gives the original size of the text. Courtesy, the Oriental Institute of the University of Chicago. (See page 3.)

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BACK COVER: The Milky Way in the Cepheus-Lacerta region, a portion of Plate 19 of the Ross-Calvert **Atlas of the Northern Milky Way.** Photo courtesy University of Chicago Press. The photograph was taken by Frank E. Ross, at Flagstaff, Ariz., October 18, 1930, using a 5-inch, f/7 Ross-Fecker camera, now the property of Mount Wilson Observatory.

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On Babylonian Lunar Theory

By O. NEUGEBAUER, *Brown University*

THE modern scientist who accidentally comes in contact with historical problems will usually be very quick to find a plausible explanation of some recorded facts. He might, for example, read about the successful prediction of a solar eclipse in antiquity; he has heard, of course, about thousands of years of most careful observation of the heavenly bodies in Mesopotamia and so the answer is at hand: the comparison with these older records showed the periodicity of eclipses and this must have been the basis of the prediction. It would seem to be looking for trouble not to be convinced by this solution.

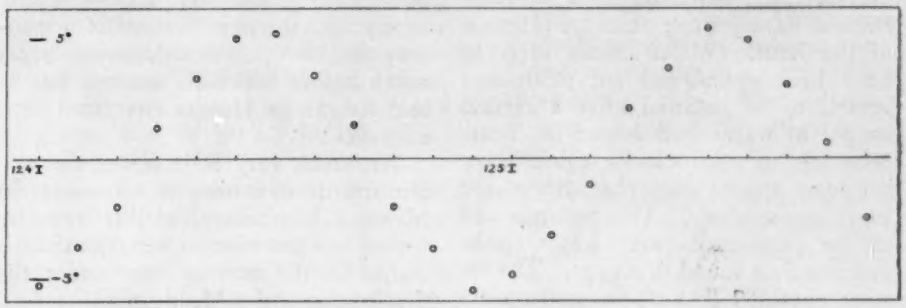
If scientific method requires the careful analysis of the concepts used in any particular statement, then the above conclusion is utterly unscientific. Let us analyze a few of the assumptions involved. If we go back from Periclean Athens about one millennium, we come roughly to the end of a period called Old-Babylonian in Mesopotamia. It was a period of great cultural activity, marking the final establishment of a Semitic population absorbing and developing the preceding Sumerian culture. What follows now is one of the most turbulent chapters in political history. Countless wars brought the most different nations and races to power. Cassites, Hurrians, Hettites, Assyrians, Medes, Persians enter the picture before the Greeks. Can we really be sure that astronomical observations were carried on systematically through all this turmoil, that archives survived the total destruction of cities, the massacre of their populations? Were astronomers of 500 B.C. able to read documents written 1,000 years earlier, written in very different characters, in different dialects, and using a terminology perhaps as different from their own as medieval terminology from modern? And how could Greek scholars make use of documents which are so difficult for modern Orientalists? We know that the Arabs were able astronomers. We have Arabic grammars and dictionaries; we can consult as many living Arabs as we wish; we know that Arabic manuscripts are preserved in libraries all over the world — and yet to predict a solar eclipse by using this material might require more than the life work of a modern scholar!

I think we are justified in looking for more trouble. What do we mean by "careful observations"? The least we must require from a careful observation is a record of its time. But how did the "Babylonians" record time? The first real "era" used consistently for the dating of documents is the Seleucid era, which begins in 312 B.C. with the independent rule of Seleucus, one of Alexander's generals, over Mesopotamia. For the preceding periods, the years are indicated in different ways. Dating by regnal years involves comparatively small uncertainty if the ruler is one of the better-known kings. But the Assyrians dated years by designating the name of a certain official called *limu*. Only a complete list of the limus would guaranty such dates. In Old-Babylonian times, years were characterized by special events, such as the destruction of a city, the building of a temple, and so forth. Again, a complete list of these year names would be needed to identify a particular year. Modern historians, using all the results of archaeology combined with astronomical chronology, were only recently forced to lower Old-Babylonian chronology by as much as two centuries. Dates before about 1600 B.C. are affected by rapidly increasing uncertainty, amounting to about one century in the middle of the third millennium B.C. This is the best we can obtain with modern methods. Chronologies given by classical writers are frequently unreliable for the latest periods and fantastic for the older periods as far as year numbers are concerned. It is safe to say that no ancient astronomer could possibly ascertain a given year before, say, 800 B.C.

Additional difficulties in the measurement of time must be mentioned. The ancient month was a real lunar month, the beginning of which was determined by the actual visibility of the crescent. Moreover, the Babylonian and late Assyrian calendar is a lunisolar calendar, that is, a calendar using 12 or 13 lunar months for one year, the addition of a 13th month being ordered whenever deemed necessary. Cyclic intercalation certainly did not start before 500 B.C. In other words, even when the year is known, the date of an observation is largely undetermined unless one knows all leap years and the complete distribution of months of 29 or 30 days.

Another necessary element of a usable observation would be the geographical co-ordinates. One cannot use in Asia Minor or Greece an observation made in southern Mesopotamia without knowing how to transform the elements. We know that the sphericity of the earth was discovered as late as Plato's time (400 B.C.). Geographical latitude and longitude do not appear before the first century A.D., and the most commonly used method to characterize the latitude of a place was to indicate the ratio between shortest and longest daylight. From this, the variation of the "seasonal hours" could be deduced by a rather crude method of interpolation. The exact solution of the problem of determining the variability of the time between sunrise and sunset for any place and for any time of the year requires spherical trigonometry, which was not sufficiently far developed before 100 A.D.

Finally, the instruments need some discussion. We do not have a single preserved astronomical instrument from Mesopotamia, but we have some textual evidence about sundials and water clocks. We have a text which lists the length of the shadow depending upon season and hour. The increase of the shadow with the hours is



The variation of the moon's latitude from month to month, part of the information contained in the ancient lunar tablet pictured on the front cover.

I	II	III	IV	V		VI	VII
2, 4 I	1, 59, 35, 33, 20	[14, 30	♏]	3, 21, 48	6, 22, 56, 12	− +	1[1, 24]	[4, 58, 39, 15, 33, 20]
II	2, 2, 21, 28, 53, 20	12, 37, [30	♐]	[3,] 32, 21	4, 24, 10, 30	− +	12, [8]	4, [33, 55, 33, 20]
III	2, 5, 7, 24, 26, 40	10, 45	[♑]	[3, 3]5, 54	2, 25, [24, 48]	− +	12, 50	4, [8, 6, 54, 48, 53, 20]
IV	2, 7, 53, 20	8, 5[2, 30	♒]	[3, 32, 9]	1, 3[0, 41, 48	+ +]	[13, 32]	[3, 42, 18, 16, 17, 46, 40]
V	2, 10, 39, [18,] 33, 20	7	[♓]	[3, 21, 12]	[3, 56, 6, 36	+ +]	[14, 14]	[3, 16, 29, 37, 46, 40]
[VI]	2, 13, 25, 11, 6, 40	[6, 36	♈]	[3, 2, 16]	6, 0, [46, 18	+ +]	[14, 56]	[2, 50, 46, 40]
[VII]	[2,]16, 11, 6, 40	[6, 36	♉]	[2, 42, 1]6	6, 1[6, 58	+ −]	[15, 38]	[2, 40]
[VIII]	[2, 1]5, 12, 36, 33, [20]	[6, 36	♊]	[2, 29,] 21, 36	4, 1[0, 42, 18	+ −]	[15, 34]	[2, 4]0
[IX]	[2, 12,]2[6, 40]	[6, 3]6	[♋]	[2,]24, 27, 12	1,[44, 53, 1]2	+ −	14, 52	2, 41, 46, 40
[X]	[2, 9, 42, 44, 26, 40]	[6,]36	♌	2, 27, 32, 48	2, 25, 49, 6	− −	14, 10	3, 2, 33, [5, 11, 6, 40]
[XI]	[2, 6, 54, 4]8, 53, 20	6, 36	♍	2, 38, 38, 24	4, 32, 4, 48	− −	13, 28	3, 28, 21, [43, 42, 13, 20]
[XII]	[2, 4,] 8, 53, 20	6	♎	2, 57, 20	6, 35, 56, 30	− −	12, 46	3, 54, 10, [22, 13, 20]

The author's transcription of the lunar tablet pictured on the front cover. In Col. I, the names of the months have been replaced by Roman numerals; in Col. III, the zodiacal signs are indicated by their customary symbols.

assumed to be proportional to the reciprocals of the integers; the variation during the seasons (assumed to be of equal length of 90 days) is supposed to be linear. It is clear that any time measurement based on these assumptions is hardly more than an estimate of the hour. Water clocks seem to have been cylindrical (or prismatic) vessels to be emptied after a certain weight of water had flowed in. Texts referring to such clocks again show the same approximate character of the basic assumptions. This reminds one of the experiences with water clocks and sundials found in Egypt. The results obtained with these instruments show that they deviate strongly from one another and certainly cannot claim any accuracy ordinarily expected.

Until now, we have not raised the question of the actual textual evidence for ancient Babylonian astronomical records. Hundreds of thousands of clay tablets have been found in Mesopotamia. Should we not expect to find astronomical material among them? As a matter of fact, we do; we have about 100 tablets which can best be described as ephemerides for the moon and the planets. We shall discuss these texts below. For the moment, it will suffice to say that all of them belong to the Seleucid or Parthian period, or, more accurately, from about 200 B.C. to the very last years before the beginning of our era. We have, furthermore, many observational reports, starting in the preceding (Neo-Babylonian and Persian) period, about planetary phenomena (heliacal rising and setting, retrogradation, and so on) and lunar phenomena (new moons, full moons, eclipses). Similar, but cruder reports are preserved in great numbers in the royal correspondence of the Assyrian empire going back to the eighth century B.C. These Assyrian reports are combined with omens which indicate events to be expected for the future of the country or the king. A few of these omens go back to the Old-Babylonian period, but I think it safe to say that the development of astronomy in Mesopotamia does not begin much before 800 B.C. and reaches its real height as late as the third century B.C.

We know very little about the origin and development of astronomy in Mesopotamia before the last centuries before our era when, after Alexander's conquest, the country was under the domination of Macedonian rulers. About this latter period, however, we are comparatively well informed. The above-mentioned ephemerides of the moon and of the planets cover the period from about 200 B.C. to 50 B.C. We know practically nothing about the theory which led to these ephemerides, but we are at least able to follow the methods of their computation and to evaluate the results.

The reproduction on this issue's front cover shows one of the oldest specimens of a lunar ephemeris, now in the collection of the Oriental Institute of the University of Chicago.[1] The tablet is, as usual, broken; the right hand part is missing but can easily be restored. The restorations made in the sections where the surface is damaged are indicated by brackets in the transcription given above. The text is an ephemeris for the full moons of the year 124 of the Seleucid era, for the year 188/187 B.C. This is indicated in the first column of the text by the number 2, 4 which means, in sexagesimal notation, 2 times 60 plus 4, or 124. The rest of the column gives the names of the months in which the full moons fall. All the numbers in the remaining columns are written in sexagesimal notation. The first number in Col. III indicates that the full moon of month I had the longitude 14° 30′ in Scorpius; the next says that the longitude of the full moon of month II was 12° 37′ 30″ in Sagittarius. This increase in longitude of 28° 7′ 30″ is maintained for the next three months; then comes a group of seven months with 30° increase, which would in turn be continued by a new group with an increase of 28° 7′ 30″. These positions are not the result of observations, but are only mean positions resulting from a rule taking into account the anomaly of the movement of the sun. It would take us far beyond the scope of this article to discuss in detail the following columns. It must suffice to say that Col. IV gives the length of daylight; Col. VI, the velocity of the moon; and Col. VII, a first approximation for the time difference between two subsequent full moons—two additional columns would be needed for corrections of this value.

The second and fifth columns require further discussion. The numbers in Col. II increase periodically between two extremes. It is easy to demonstrate that the period of this oscillation is exactly the period of the anomalistic month, and this led to the assumption that the numbers represent the variable diameter of the moon, expressed in units which are equivalent to one fourth of a degree. The results would be very accurate indeed, varying between about 29′ 26″.9 and 34′ 16″.2.

Serious objections must be raised, however, against this interpretation. First of all, no units of one fourth of a degree occur anywhere else. Secondly, this column is used to find the

[1] I am indebted to the authorities of the Oriental Institute for permission to publish a photograph of this tablet for the first time.

length of the months; and, finally, it is hard to see how such an accuracy could be reached with primitive sighting instruments.[2] Both the units and the purpose of this column would agree excellently with an interpretation involving the relative velocity between sun and moon, but the average value appears to be too high. In the present state of affairs, it seems to me therefore necessary to admit that no certain interpretation of this column is available and that the value used for the lunar diameter is unknown to us.

The values of Col. V can best be described graphically. The units correspond to 6/5 degrees and represent the celestial latitude of the moon at opposition. The method of computing these values cannot be described here in detail, but the diagram on page 3 shows the results obtained for the variation of the moon's latitude. The period of this function corresponds very closely to the relation that 293 nodical months equal 270 synodic months.

From ephemerides of the described type, tables for eclipses were obtained. Eclipses are only possible for small values of the latitude of the moon and therefore only those months in the above complete list are of interest where the values in Col. V are closest to zero, i.e., IV and IX. From the latitude, an estimate is obtained for the magnitude of the expected eclipse. One could hope to deduce from this computation the diameter of the moon, but unfortunately no more than the ratio of the diameter of the moon and the diameter of the shadow can be deduced: From the comparison of eclipse magnitudes with modern values one can show that half a degree must be a fairly good estimate of the moon's diameter. But until we find texts which inform us about the duration of the totality, we cannot answer exactly the question about the value for the dimension of the angular diameters of sun and moon assumed by the Babylonian astronomers. What we know is only that the results for the prediction of lunar eclipses were quite satisfactory when compared with the low accuracy of ancient instruments. In the case of solar eclipses, however, the methods described above were not sufficient to predict the visibility of a solar eclipse. For this purpose, the parallax of the sun and geographical co-ordinates should be considered, elements which play no role in the known Babylonian

(Continued on page 10)

[2]Ptolemy finds 31′ 20″ and 35′ 20″.

Amateur Astronomers

MILWAUKEE MIRROR ALUMINIZED

After a lapse of about five years, the 13-inch mirror of the Milwaukee Astronomical Society's reflector, located out at Prospect Hill, has had its face lifted. Edward Halbach, director of the observatory, was the beautician, so to speak. Not content with teaching at a local university, he has a defense job on the side with a company which has the means to aluminize mirrors on a small scale. After some unsuccessful attempts, he finally succeeded in coating the mirror with a beautiful finish.

On October 1st, a few of the members including the writer journeyed out to the observatory and with some difficulty installed the mirror in the tube. Most of the work was done by Edward Schoenke and Joe Lovinus. Collimation of the mirror was out of the question because of a slight drizzle at the time, but this will be taken care of at the earliest opportunity. About the best we could do was to train the big gun on a farmer's field about half a mile away, and try to count the kernels of corn on ears lying on the ground and to determine if it was just ordinary corn or popcorn!

CARL GRIESBACHER
Milwaukee Astronomical Society

BARNARD ASTRONOMICAL SOCIETY REORGANIZES

In our October issue, the transfer of the Chattanooga Observatory from public ownership to the University of Chattanooga was announced. Further word has come of the details of the university program. Courses in astronomy are offered at the university, with laboratory work to be done at the observatory. The observatory will also be available one evening a week during the school year, weather permitting, to students of the community's schools and to adults.

On September 12th, a group met to reorganize the Barnard Astronomical Society, founded in 1923 by B. M. Annis. Clarence T. Jones, local architect, was elected permanent president; he is to serve the university also as instructor in astronomy and manager of the observatory.

Other officers unanimously elected are: Burton Jones, annual president; Llewellyn Evans, vice-president; Josh Warner, secretary; Arthur Brading, treasurer. Regular meetings of the society are held at the university the last Thursday of each month.

CINCINNATI OBSERVERS TO REPORT

At the meeting of the Cincinnati Astronomical Association to be held on Friday, November 10th, at Cincinnati Observatory, a short lecture will be followed by reports of observer groups on occultations and other observational activities.

THIS MONTH'S LECTURES

Cleveland: Dr. Paul Annear, of Burrell Observatory, will address the Cleveland Astronomical Society on "The Calendar Old and New" at the November 3rd meeting, 8 p.m. at the Warner and Swasey Observatory.

Detroit: On Sunday, November 12th, Lt. Maude Squire Rufus, CAP, will speak to the Detroit Astronomical Society on "More Adventures in Celestial Navigation by 'Flying Grandma'." The society meets at 3 p.m. in Room 17, Wayne University.

Madison: Following discussion of the November sky at the meeting of the Madison Astronomical Society, Washburn Observatory, November 8th, W. R. Binney will speak on "The Dawn of Astronomy."

New Haven: There will be two meetings of the New Haven Astronomical Society in November. "Observational Methods—Old and New" is the title of a talk by Charles A. Federer, Jr., of Harvard Observatory, on Saturday, the 4th. William Von Arx, of the Institute of Physics of Yale University, will speak on "Geological Interpretations of the Surface of the Moon" on Saturday, November 25th. Both meetings will be held in the evening at Yale University Observatory.

New York: "Volcano Paricutin" will be the subject of the talk by Dr. Clyde Fisher, honorary curator, Hayden Planetarium, before the Amateur Astronomers Association on November 1st. The meeting is at 8:00 p.m. in the Roosevelt Memorial lecture hall at the American Museum of Natural History.

Philadelphia: "Recent Developments in Transit Circle Design" will be the subject of the lecture by C. B. Watts, U. S. Naval Observatory, before the Rittenhouse Astronomical Society on November 10th.

PROGRESS REPORT AT CLEVELAND

By W. W. MORGAN, *Yerkes Observatory*

A JOINT meeting of Section D (Astronomy) of the A.A.A.S. and the Ohio Neighborhood Astronomical Group was held on September 14th at the Warner and Swasey Observatory in East Cleveland. The meeting consisted of two parts: a group of papers on various subjects, and a symposium on objective-prism spectra.

New results on the problem of the presence of oxygen and water vapor in the atmosphere of Mars were presented in a paper submitted by Dr. W. S. Adams, of Mount Wilson. The spectrum of Mars was photographed with the 100-inch telescope on the remarkable IV-N infrared emulsion developed by the Eastman Kodak Company. This emulsion has fine grain and high contrast and remarkably high speed, when the other characteristics are taken into account.

The spectrogram used was obtained on October 29, 1943, at a time when Mars was moving toward the earth at a relative speed of around five kilometers per second. This would mean that any spectral lines originating in the atmosphere of Mars would be shifted slightly to the violet of their normal positions. In particular, if there were considerable amounts of oxygen or water vapor in the Martian atmosphere, they would produce lines which would be shifted slightly with respect to the strong lines of these substances originating in the atmosphere of the earth.

A careful inspection of the spectrogram failed to show any trace of lines of oxygen or water vapor in the atmosphere of Mars; and, in addition, measures of the positions of a number of terrestrial lines of these molecules showed that their positions were not appreciably disturbed by any Martian contribution. An estimate of an upper limit of one per cent of the amount of terrestrial oxygen and water vapor would appear liberal for the Martian atmosphere. This is in agreement with earlier results from Mount Wilson, but the quality of the present observational material is considerably superior to that used formerly.

In addition, a detailed comparison of the spectra of Mars and Venus shows no evidence for the presence in the spectrum of Mars of the three bands of carbon dioxide so conspicuous in the infrared spectrum of Venus.

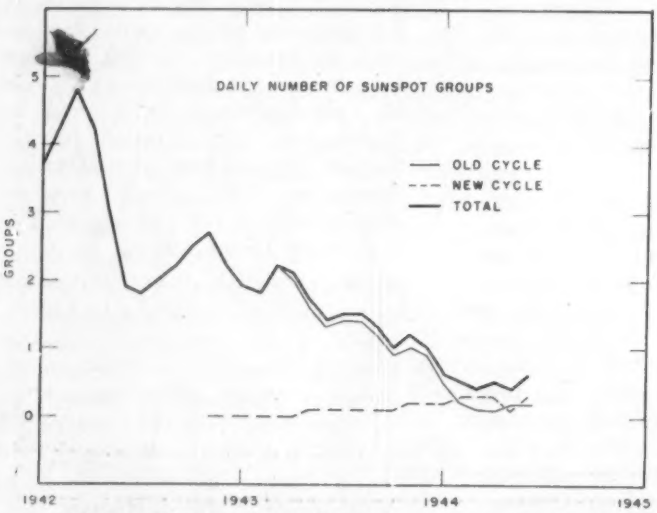
In another paper from Mount Wilson Observatory, Dr. Seth B. Nicholson reported on the time of the latest sunspot minimum. In April, 1944, no spots were observed at Zurich, Switzerland; during the same period two very small spot groups were seen at Mount Wilson. Since April, sunspots have been relatively more numerous and it seems likely that the date of the current minimum will be assigned at Zurich near 1944.3.

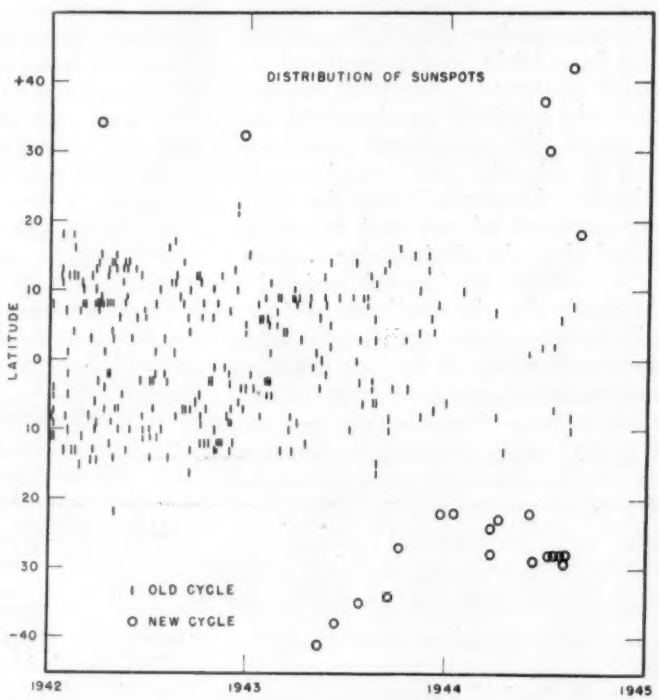
Dr. Nicholson showed two lantern slides, reproduced here, to indicate the gradual increase of spots in the new cycle and the rapid falling off of the old ones, and the distribution of the spots in solar latitude.

As shown in the chart at the right below, the first high-latitude spots observed in connection with the beginning of the new cycle were seen at Mount Wilson in 1942; six high-latitude groups were found in 1943, and 17 during the first eight months of 1944. Meanwhile, the number of old-cycle spots systematically decreased from 187 in 1942 to 15 in the first eight months of this year.

The magnetic polarity of preceding spots in the northern hemisphere of the sun (in the new cycle) is that of the south-seeking pole of a compass; in the old cycle the polarity is opposite. This is the fourth minimum since magnetic fields were first observed in sunspots: the arrangement of polarities has reversed at each minimum.

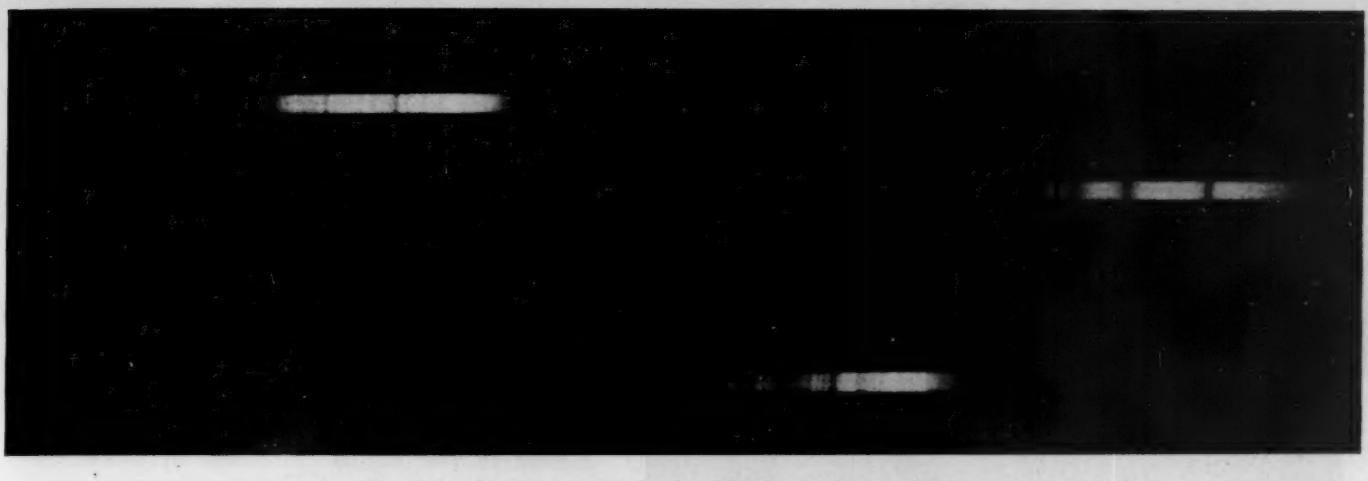
The lengths of the last three complete cycles, measured from minimum to minimum, have all been less than 11.1 years, which is the average value for the last 200 years; they are 10.0, 10.2, and 10.5 years, respectively. Dr. Nicholson hazarded a guess that the cycle now beginning will be longer than any of these, basing his guess on the fact that these three are shorter





(Above) The total number of sunspot groups has fallen rapidly since 1942, when the first spots of the new cycle appeared.

(Right) The gradual migration of spots toward the solar equator and the appearance of the new-cycle spots in high latitudes is shown here. Both diagrams are from Mount Wilson Observatory.



Part of an objective-prism plate obtained with the 24-inch Schmidt camera of the Warner and Swasey Observatory.

than the average. He is skeptical of a report by W. Gleissberg, in the *Astrophysical Journal*, July, 1944, who expects the next maximum to occur before May, 1948, with a probability of 19 to 1.

Among other papers presented, of special interest was an investigation of the brightest stars associated with the great Andromeda spiral system. Dr. C. K. Seyfert and Prof. J. J. Nassau, of the Warner and Swasey Observatory, find that there are around 2,500 supergiant stars in the Andromeda system, each of which is at least 1,000 times as bright as our sun. The investigation was made on photographs obtained with the new 24-inch Schmidt telescope at Cleveland. We thus actually have a far more complete census of the supergiants in this distant system than in our own galaxy. A study of the faint extensions of the Andromeda nebula on the Schmidt telescope plates confirms the photoelectric results of Stebbins and Whitford in showing that the system is considerably flattened.

New methods in stellar spectroscopy was the topic of the address of the retiring vice-president of Section D, Dr. Otto Struve, of Yerkes Observatory; the paper was reviewed in this magazine last month, page 8. Dr. C. C. Wylie, of the University of Iowa, gave a report on the recent daylight meteor observed in several midwestern states, and described on the Observer's Page last month.

The speakers at the symposium on objective-prism spectra were: Drs. Nassau and Seyfert (Case), Bok (Harvard), Keenan (Washington, D. C., and Yerkes), Vyssotsky (McCormick), Lee (Dearborn), and Morgan (Yerkes). Perhaps the most interesting single feature was the presentation of the first results obtained with the 24-inch objective-prism Schmidt camera of the Warner and Swasey Observatory. Spectra obtained with this instrument are of such high quality that a new standard of accuracy in the classification of faint stars should be attainable. In spite of the location of the observatory in the city of East Cleveland, the spectra show a considerable number of features for stars as faint as the 12th magnitude.

In addition to determining ordinary spectral types, it is possible in the case of the yellow and red stars to identify supergiants, giants, and dwarfs, with ease; this means that mass production of accurate parallaxes of faint stars is now possible. Some of the features observed change with the spectral type, or temperature, of the stars; others change with the size, or luminosity, within each spectral type. A study of the latter in connection with stars of known distance makes it possible to determine the individual distances of thousands of stars for which no other method is satisfactory.

Drs. Nassau and Seyfert presented the results of a comparison of their spectral types for stars in the neighborhood of the north polar sequence with the types determined at Harvard, Bergedorf, and by Keenan at Yerkes. Their lantern slides of objective-prism spectra obtained with the Schmidt telescope showed that it is possible at a glance to pick out yellow giants and dwarfs. The most useful part of the spectrum for the *G5-K0* stars is probably the violet region; the strongest absorption of cyanogen characteristic of giant stars is located there.

Dr. Keenan described certain methods of identifying supergiants on spectra of the kind now being obtained at Case. It should be possible to pick out the extremely brilliant yellow and red supergiants on plates of this type; examples of these objects among the brighter stars are Epsilon Aurigae, Delta Canis Majoris, and Mu Cephei. The ability to recognize these stars by their spectra makes it possible to discover and study exceedingly distant stars in our galaxy.

Dr. Bok outlined some of the spectroscopic work to be undertaken at Harvard after the war. Dr. Vyssotsky called attention to certain lines of low-dispersion spectroscopic investigations which appear to be very promising for the future. Dr. Lee described the Dearborn spectroscopic survey for faint red stars.

In conclusion, we may say that investigations with objective-prism spectra seem likely to proceed in two directions: (1) The determination for fainter stars of spectral types of the same kind as those in the Draper catalogue; (2) The refinement of the types for the brighter stars and the spectroscopic determination of distances of large numbers of the latter. Schmidt cameras similar to that at Cleveland are eminently suited to work in both of these directions.

The INDEX for Volume III

is in preparation. It will be similar to previous indexes, including title page, author, title, subject, and topic references. Inclusion of the whole number of each issue on each page of Volume III will facilitate use of this index. It is invaluable for quick reference and for best use of the volume. Send 25 cents, and your copy will be mailed as soon as printing is completed.

The Indexes for Volume I and Volume II are still available. Cost of these is 25 cents each.

Sky Publishing Corporation
Harvard College Observatory
Cambridge 38, Mass.

COLOR IN THE SKY

By Charles O. Roth, Jr.

Color may be of the sky, or in the sky, ranging from the clouds and rainbows in our own atmosphere to the distant stars. Color in the sky is discussed here and in the Hayden Planetarium this month.

Sunset colors provide one of nature's outstanding spectacles.

THE colors in the sky might be interpreted as nature's appeal to the better side of mankind. When nature displays her colored arts, all of us are susceptible to some emotional reaction. Our day-to-day moods, frequently, are but a partial reflection of the color of the sky.

During daylight hours, the colors in the sky, for the most part, have as their source the light of the sun. The changes and variations in the sun's light, as we see them from the earth's surface, are caused by the earth's atmosphere.

The sun's visible surface is called the *photosphere*, or "light sphere." From the photosphere a continuous emission of radiant energy is streaming forth in every direction, a small fraction of which falls upon that side of the earth facing the sun. The radiation is emitted through a wide range of *wave lengths*, from the hertzian or radio waves, as long as 15 miles, to the infinitesimally small gamma rays, as short as 5×10^{-10} centimeters. Often, it is convenient to consider radiation in terms of *frequency*, which means the number of waves or vibrations emitted in one second. All radiation has the constant velocity of light in empty space; the shorter wave lengths possess the higher frequencies, because wave length times frequency equals velocity.

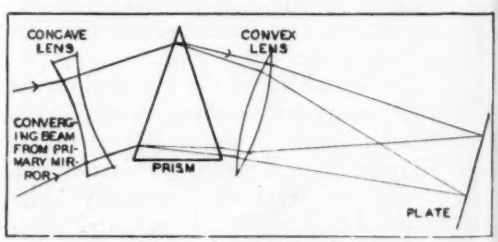
Light is the sensation produced and interpreted by the brain when something enters the eye and stimulates the retina. The eye, like most receiving apparatus, is sensitive to a limited range of wave lengths or frequencies. Obviously, within this narrow band there exist different wave lengths, among which the brain distinguishes by a sensation called color. Color blends and hues result when different wave lengths are received at the same time. Simultaneous reception of all of the wave lengths in this narrow band produces the sensation called white light. Sir Isaac Newton, in 1666, was the first to demonstrate that the white light of the sun is composed of the entire range of colors. It was stated above that all radiation has the constant velocity of light in empty space. In passing from one medium to another, however, the individual wave lengths acquire different velocities and, consequently, are separated. Newton admitted sunlight into a darkened room through a narrow slit placed before a glass prism, and formed a spectrum having the colors of the rainbow, namely: red, orange, yellow, green, blue, indigo, and violet. The red end of the spectrum possesses the longer wave lengths and lower frequencies, while the violet end exhibits the shorter wave lengths and higher frequencies.

The commonest of all the colors in the sky, and, indeed, one of the most beautiful, is the blue of the sky. The other colors are neither so extensive nor so persistent as the blue, being for the most part confined to the times and general direction of sunrise and sunset. The blue of the sky results from scattering of the sun's light when it strikes the outer fringes of the earth's atmosphere. This scattering is first effective upon the shorter wave lengths, that is, the violet and blue colors. As the interference is intensified by the increase in the number of minute particles encountered, either by an increase in the quantity of these particles in the air, or a lengthening of the path of the light through the atmosphere, the scattering of the colors develops progressively through the spectrum. Since the violet color is initially weak, it is rapidly depleted as it passes through the air, and usually can be seen only from very high altitudes. From the earth's surface, violet is completely submerged by blue.

The sun's altitude above the horizon determines, indirectly, the color of the sky. The length of the path of the sun's light through the atmosphere depends on the sun's position in the sky; the path is shortest when the sun is on the meridian, and longest when the sun appears on the horizon.

From the foregoing statements, and from observation too, it seems reasonable to predict that the sky will be colored with the richest blue at noon, near the zenith, on days when the atmosphere is clearest. As the time departs from noon, both before and after, the blue color will blend gradually with green, yellow, orange, and red colors, or a combination of these tending to appear white. At noon, on clear days, the blue color fades perceptibly from the zenith toward the horizon.

The color of the sky at sunrise and sunset will be determined largely by the state of the atmosphere, that is,



To photograph a spectrum, incoming light must be sorted into its component parts by a prism (or other means), and brought to a focus on the photographic plate.

by the quantity of minute particles present. When the atmosphere is clearest, the yellow-orange colors predominate. As the clarity of the atmosphere diminishes, the yellow-orange colors are absorbed successively by the orange, the orange-red, and finally the red, which has the ability to penetrate greater thicknesses of atmosphere.

Twilight is the interval between the end of direct sunlight and the total absence of sunlight. Morning twilight precedes sunrise and evening twilight follows sunset. During both twilight intervals the sun is below the horizon, but its light shines upon the upper atmosphere and is reflected downward toward the earth. The duration of twilight depends upon the season of the year and the latitude of the observer. After sunset, *civil twilight* prevails until the sun's center is six degrees below the horizon. At that time the light becomes too dim for the usual outdoor activities of the daytime. *Astronomical twilight* terminates when the sun's center is 18 degrees below the horizon. The sky then is sufficiently dark for the faintest stars to be observed in the zenith. The twilight bow, or arc, seen in a clear sky in the direction opposite the sun, is merely the earth's shadow cast upon the upper atmosphere. In the evening it rises above the eastern horizon, and its dull, violet-blue color slowly engulfs the sky.

The discussion thus far has been directed toward the color of the sky. Many beautiful and fascinating colors appear in the sky which are not necessarily the color of the sky. Of these, some originate within the atmosphere, while others originate far outside the earth's atmosphere, and are entirely independent of it.

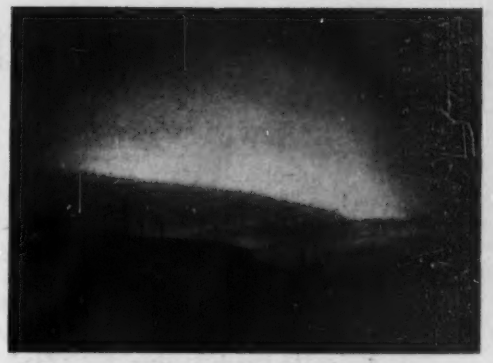
First among the striking colors *in* the sky, originating within the atmosphere, is the color of the clouds. In general, clouds become visible when they reflect light, and their color is essentially the color of the light by which they are illuminated. Frequently the sky is partially or totally covered with a relatively thin layer of clouds, and the sun or a bright moon may shine through the layer. When the condensation of the clouds is in the form of ice crystals and snowflakes, halos are formed as the result of refraction and reflection of the light. Under similar circumstances, coronae are formed when the condensation is in liquid form, that is, water droplets. The water droplets, however, create an interference with the light called diffraction. Occasionally, both halos and coronae exhibit the colors of the spectrum, but more frequently they are white.

Mars' ruddy hue helps us distinguish this planet among the stars.

One of the most familiar color phenomena in the atmosphere is the rainbow, that is, the solar rainbow; for on rare occasions, the moon provides a source of light to cause a lunar rainbow. In either case, the direct light is refracted and reflected by raindrops, usually near the end of a shower when openings develop among the scattering clouds through which the direct light can shine upon the falling drops of water. The rainbow is seen by an observer located between the falling rain and the source of light; a straight line connecting the sun with the center of the rainbow passes through the eye of the observer. For this reason, no two individuals can see exactly the same rainbow. Since the radius of the primary bow is about 40 degrees, it is possible to see a primary rainbow, from the surface of the earth, only at those times when the sun is less than 40 degrees above the horizon. From an airplane, the rainbow may appear as a raincircle, with the shadow of the plane at its center.

Perhaps the most mysterious colors to appear in the sky are those of the auroral lights. The *aurora borealis*, or northern lights, seems to emanate from the regions of the north magnetic pole, and the aurora australis, from the regions of the south magnetic pole. Auroras are more frequent and more widespread when sunspots are numerous; red and green hues predominate.

Under very favorable atmospheric conditions, a faint white glow, called the *zodiacal light*, may be observed in the sky on a moonless night. It is brightest and widest near the horizon, and dims and tapers upward along the path of the ecliptic. The best time to observe the zodiacal light is when the ecliptic is nearly perpendicular to the horizon. For mid-northern latitudes, this is most nearly so in the evenings of March, toward the west; and toward the east, before dawn, in September. In the tropics, the zodiacal light is visible throughout the year, both morning and evening. When the sky is especially clear some observers have seen a small spot of light, directly opposite the sun, called the *gegenschein*, or counterglow.



Delicate coloring is often perceptible in an aurora.

The planets exhibit a variety of colors, depending upon the color of the surface reflecting the sunlight. Venus appears white because the sunlight is reflected from dense clouds which envelop the planet. Mars appears red to the unaided eye, but through the telescope exhibits white polar caps and a green-brown equatorial belt. Both Jupiter and Saturn are pale yellow to the unaided eye, but exhibit color bands through the telescope. Uranus and Neptune have a pale green tint.

All of the stars appear tinged with color, depending on the wave lengths in which their radiation is strongest. The perception of color diminishes rapidly as the apparent brightness decreases. Among the bright stars which exhibit definite color to the unaided eye are: Sirius (blue-white), Capella (yellow), Arcturus (orange), and Antares (red). Albireo, marking the base of the Northern Cross in Cygnus, is an outstanding example of a double star having contrasting colors. A relatively small telescope separates the pair, and reveals one star to be blue and the other golden-yellow.

To the layman, the colors in the sky may simply stimulate and enrich the appreciation for the beauty that abounds everywhere in nature, but to the astrophysicist, the colors in the sky become the key that unlocks the gates to knowledge. Spectroscopy is the analysis of the radiations from luminous sources, and has revealed facts about outer space which challenge our imagination. The temperatures, compositions, sizes, distances, and other physical characteristics of the stars, nebulae, and galaxies are disclosed by the "color" of their light.

One taper lights a thousand,
Yet shines as it has shone;
And the humblest light may kindle
A brighter light than its own.

NEWS NOTES

By Dorrit Hoffleit

DOUBLE WHITE DWARF

Variety in double stars seems to be the order of the day. Last month we reported the discovery of a pair composed of one red and one white dwarf. Now Dr. W. J. Luyten announces his discovery of a pair made up of two white dwarfs. It is known as LDS 275 (Luyten Double Star No. 275). The components are both somewhat fainter than 14th magnitude photographic, and were discovered by their common high rate of proper motion, 0".35 a year. They are separated by 3".5. This is believed to be the first known double star with both components white dwarfs.

R.A.F. ECLIPSE EXPEDITION

Flight Lt. D. J. Holland found himself fortunate in being in West Africa at the time of the total eclipse of the sun on January 25, 1944. Being an astronomer, he organized an R.A.F. eclipse expedition, but he himself was the only astronomer present. The success of the expedition, organized within just one week, and equipped with nothing but what could be found on the premises, is amazing. Observations were made both from the ground and at altitudes of 15,000 and 25,000 feet. Meteorological and magnetic observations were obtained by a French meteorologist, M. du Chaxel. The corona, chromosphere, flash spectrum, and other phenomena were recorded by a party of 15 who had to journey 135 miles by road through the African bush.

The equipment was not elaborate. The one telescope was a theodolite to which a camera of 5-inch focal length was attached. The only prism was borrowed from a school at Freetown, and fitted to a 20-inch camera to photograph the flash spectrum during the first half second of totality and quickly removed so that the camera could be used for direct photography of the corona. Sketches of the corona were also made.

From the air at 15,000 feet, three sets of photographs were obtained with 8-inch and 14-inch cameras. Horizontal views were also photographed to a distance of 200 miles in the moon's shadow. From 25,000 feet, the shadow cast on the haze layer appeared so distinct that the pilot could check his course on it.

Dr. Holland comments (in the *Journal* of the British Astronomical Association) that the success of the expedition depended initially on there being at Freetown the only available nautical almanac. The final success depended on close co-operation among men not trained in astronomy.

BRILLIANT CITIZEN OF A SCIENTIFIC WORLD

Science and Culture, a journal published at Calcutta, in its May number, gives an account of the scientific achievements of the gifted young astrophysicist, S. Chandrasekhar, who has recently been elected a Fellow of the Royal Society of London.

After completing his undergraduate work at Madras, Chandrasekhar went to Cambridge, England, where he received his Ph.D. Then he came to America, first to Harvard, then to Yerkes Observatory, where his brilliant scholarship and teaching ability have attracted research students. In this country he has published profusely and profoundly on fundamental problems of stellar structure and evolution, especially on the nature of those puzzling stars, the dense white dwarfs.

Science and Culture deplores the fact that the country of Chandrasekhar's birth could not offer him a post befitting his abilities, but continues, "We are, however, glad to learn that attempts are being made to get him back to India. The amount of scientific talents in this country is not so large that we can spare a man of Chandrasekhar's type. He should be in this country, training our young hopefuls in the methods of science, and if he is allowed to remain longer in the U.S.A. the gain will be all on the side of that country, and the loss will be India's." As scientists, we should maintain that wherever a man like Chandrasekhar works, the gain will be in the advancement of science in general, and not to a particular country.

An editorial footnote, however, makes us ponder sadly on the political aspects of the case: "But in spite of the appreciation of the American men of science for Chandrasekhar, is it not somewhat shocking to find that, according to U.S.A. law, he cannot be a citizen of that country."

For a long time Dr. Chandrasekhar has been a consultant at the Aberdeen Proving Ground, actively helping in the American war effort. His eventual return to his own country will constitute a definite loss to his colleagues and students in this country; but science will not be the loser.

NEW COMET IN SOUTHERN SKIES

On September 13th, a new comet was discovered by D. C. Berry, director of the comet section of the New Zealand Astronomical Society, according to a cablegram transmitted from the Carter Observatory at Wellington, New Zealand. Its position was given as $7^h\ 40^m$, $-75°$, in the constellation Volans, and the daily motion as 22^m east and $3°.2$ north (approaching the sun). At the time of its discovery, the comet was already of 5th magnitude and had a tail about one degree long.

A second report from Carter Observatory was sent, at his request, to L. C. Cunningham, now at Aberdeen. On September 16th, the comet had faded to magnitude 6-7 and was at $8^h\ 40^m$, $-65°$.

Thereafter, the comet must have been lost to view near the sun, but re-discovery in the Leo-Crater region was possible during October, when this part of the sky was rising a few hours ahead of the sun.

ON BABYLONIAN LUNAR THEORY

(Continued from page 5)

methods. The information obtained from the ephemerides will therefore only suffice to exclude a solar eclipse but not to predict it.

The above-described procedure for computing ephemerides of the moon is based on the knowledge of common periods of lunations, the moon's latitude, the moon's and the sun's anomaly, and so forth. It is therefore evident that the Babylonian astronomers were aware of the periodic character of the resulting phenomena. There are good reasons for the assumption that also the special relation known as the saros (242 nodical months = 223 synodic months) was familiar to them, but it is historically incorrect to apply the name *saros* to this relation and to assume that eclipses were predicted simply according to a cycle. It was Halley who introduced this notation in 1691 combining and emending in an unjustified manner certain passages in Pliny and other ancient authors. In Halley's time, no first-hand documents about Babylonian astronomy were available. This situation is now much changed, giving us the possibility of revising slowly the traditional picture. But much work remains to be done before we know even the most fundamental steps in the early history of astronomy.

ASTRONOMICAL ANECDOTES

MORE NOMENCLATURE

THIS copy is being written immediately after that for October, so while I am warmed to the subject I might be permitted to go a step or two farther in the matter of better nomenclature.

At the recent Philadelphia meeting of the American Astronomical Society, the president, Dr. Harlow Shapley, commented twice on expressions raised by members whose papers were presented. One was in reference to *lucid Pleiades,* which is, without knowing that the author of the paper was Dr. J. A. Pearce, director at Dominion Astrophysical Observatory, a slight Britishism. To my ear, such expressions are not too displeasing; certainly I prefer to hear such a word as lucid rather than the awkward and ubiquitous expression "naked-eye." Lucid is defined as bright; the paper was devoted to the bright Pleiades.

Of course, all Pleiades stars are bright; they are the stars seen by the ancients and named for the daughters of Atlas and Pleione. And in passing it might be noted that whoever named the individual stars of the cluster we see with the unaided eye did a very inconsistent thing when he assigned the names Alcyone, Taygeta, Maia, Electra, Merope, and Atlas. What is Atlas, the father, doing amongst them? I thought these stars were supposed to be the daughters of Atlas! And while a Pleiad or two were to be omitted, why weren't the lost Pleiads chosen—Electra or Merope—instead of two never reported missing—Celaeno and Sterope? Electra is reported to have left her place in heaven so she might not have to see the destruction of Troy, founded by her son Dardanus; Merope became mortal as a result of her marriage to Sisyphus, king of Corinth.

But to go on with the Pleiades: Is it proper to refer to any stars as Pleiades unless they are the stars so named by the ancients? We might say, the stars of the Pleiades cluster, to avoid coining a more awkward expression, but surely it is not correct to refer to one of the very faint stars of the 500 in the cluster as "one of the Pleiades."

The other objection raised by Dr. Shapley was to the use of the expression *sub-dwarf* by Dr. Dean B. McLaughlin, to characterize the initial pre-catastrophic state of a nova. One hardly knows what to say in such a situation. The expression white dwarf has not been attacked, but it certainly should be. So should statements about blue, green, lilac, sapphire, and lavendar stars. I might let them get away with a bluish-white star, as contrasted with a creamy-white star, but to label any star as blue is a little severe, to my presumably normal eye. There's some astigmatism there, but no color blindness. Green stars! Almost all of them are near orange or yellow ones, yet we permit the subjective effect to creep into the descriptions, particularly of the little star near Antares. Any kind of a star except another orange-reddish one would appear green, in that place. And, of course, what color does Betelgeuse really have? Can we call it red? Is even Hind's Red Star in Lepus really red? Or V Aquilae?

White dwarfs are probably going to be found to be of the same colors as the stars of *B, A, F, G, K* classes, whatever they are. The "reversed 7" diagram is becoming a "reversed Z" diagram as this real dwarf branch of the spectrum-luminosity or spectrum-absolute magnitude diagram fills in. The stars we have heretofore called dwarfs are main-sequence stars, ranging from giant *B* stars to dwarf *M* stars. We might call stars below the main sequence *dwarfish,* as opposed to the real dwarfs, miscalled white dwarfs; then those above the main sequence, yet not quite up to the true giant branch, might be *giantish* stars. Above them are the giants and the supergiants.

Dr. Payne-Gaposchkin has already commented on the term *supernovae;* they are not super in the nova sense; they are no "newer" than other "new" stars. They are high-luminosity novae. For that matter, the word nova itself is not very exactly used, yet there is no immediate prospect that the term will ever be used exactly; no really newborn stars have been observed. Because of the extreme unlikelihood of misinterpretation, the term nova to describe the objects improperly called temporary stars is preferable because unambiguous.

The situation is somewhat similar with respect to the use of the word *galaxy,* especially in the plural. There have been arguments in print that the word galaxy must be applied only to the Milky Way or to "an assemblage of brilliant or noted persons or things." Very well; stars are brilliant things. So a galaxy is an assemblage of stars. Certainly it is somewhat silly to use the word nebula for both clouds of gas and clouds of stars, now that we are able with telescope and spectroscope to distinguish between the two types of object. Let the word nebula be used exclusively for those gaseous objects or gas-strewn fields where the largest aggregations of matter are at best of the order of size of groups of molecules; galaxies then are those objects consisting of aggregations of stars plus other stuff.

And "island universes" is the greatest abomination of all! The expression should never appear without quotation marks; the word universe should be reserved for all of creation—everything there is. Dr. Shapley's term *metagalaxy* for the visible universe I approve, yet I don't understand the etymology of it. It is a coined word for the occasion, not likely to be useful to anyone else; its position is somewhat similar to the word *parsec.*

The door seems to be open to a new committee of the American Astronomical Society, formed to establish uniformity of nomenclature. But let the dictionaries not be consulted as last authorities. when they clash with the opinions of the majority of contemporary astronomers! R.K.M.

BEGINNER'S PAGE

Space limitations in this issue preclude inclusion of the Beginner's Page. Next month the series on "Man and His Expanding Universe" will be resumed.

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SKY PUBLISHING CORPORATION
Harvard College Observatory **Cambridge 38, Mass.**

STARS, SUN and PLANETS - 1943 MAY 12, G.D. (WEDNESDAY)

G.M.T.	G.H.A. of First Point of ARIES = G.H.A. ♈ 00m	10m	20m	30m	40m	50m	G.M.T.	VENUS −3·6 G.H.A.	Dec.	MARS 1·0 G.H.A.	Dec.
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01	243 56	246 26	248 57	251 27	253 58	256 28	01	153 15	25 41	253 50	6 02
02	258 58	261 29	263 59	266 30	269 00	271 31	02	168 14	25 41	268 50	6 01
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23	214 50	217 21	219 51	222 21	224 52	227 22	23	122 59	25 42	224 05	5 46

G.M.T.	G.H.A. of SUN 00m	10m	20m	30m	40m	50m	SUN'S Dec.	G.M.T.	JUPITER −1·5 G.H.A.	Dec.	Planets
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23	165 56	168 26	170 56	173 26	175 56	178 26	18 06	23	102 27	22 16	

Venus is a brilliant object observable low in the west for some time after sunset. Mars is easily observable in the east for a few hours before sunrise. Jupiter is well placed for observation in the west for a few hours after sunset.

AIR ALM

By W. J. Eckert, *Director*,

Communicated by Capt. J. F. Hellweg, U.S.

SINCE the development of the sextant and the chronometer, the navigator has been able to determine his position accurately by measuring the altitude of a celestial body. At sea the altitude is usually measured from the sea horizon; in the air, from the horizon indicated by a level bubble. Many aids to navigation which do not depend on astronomical observations have been developed, but the determination of position from observed altitudes remains of primary importance.

Before the time of Capt. Sumner, the altitude was usually measured near the meridian and near the prime vertical; the former for the determination of latitude and the latter for the determination of longitude. At present the altitude is measured whenever convenient and is used to determine a line of position at right angles to the bearing of the observed object. This line of position, or Sumner line, is a segment of the small circle on the earth's surface containing all the points from which the observed altitude could have been obtained. The altitude observed from a point within the circle would be greater and that from a point without would be less than that observed on the circle, the difference in altitude in each case being equal to the angular distance along the earth's surface from the point to the circle.

The general method of computation now followed for the determination of the line of position is that of Marcq Saint-Hilaire. In using this method the navigator adopts an assumed position on the earth and computes the altitude and azimuth which the object would have as seen from that point at the time of the observation. The difference between this computed altitude and the one observed with the sextant is the distance from the assumed point to the line of position, and the line of position is at right angles to the computed azimuth line.

Astronomical navigation thus requires the navigator to find the computed altitude and azimuth of any object he wishes to observe as seen from some point in his immediate neighborhood at the time of observation. For the navigator to compute the required altitude and azimuth completely in the limited time at his disposal is impossible. On the other hand, there are so many objects which may be observed from so many places and at so many times that performing all the computation for him is out of the question; in addition to the cost, the problem of finding the required data among such quantities of figures would be formidable. The practical solution of the problem has been to do most of the calculation in a central bureau and to leave a few simple operations to the navigator.

Because of the simple linear relationship between time, longitude, and hour angle, the calculation of the local hour angle by addition and subtraction of given quantities is left to the navigator. The conventional method provides him with a nautical almanac or an air almanac for obtaining local hour angle and declination and with navigation tables for determining from local hour angle, declination, and latitude, the altitude and azimuth. This is the general scheme for sun, moon, planets, and stars. However, there are many tables and mechanical devices which take

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GCT	☉ SUN GHA	Dec.	♈ GHA	VENUS −3.6 GHA	Dec.	MARS 0.9 GHA	Dec.	JUPITER −1.5 GHA	Dec.	☽ MOON GHA	Dec.	☾ Par.
h m	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	
0 00	180 56	N17 51	228 54	138 15	N25 41	238 49	S 6 03	116 40	N22 18	90 38	N15 42	
10	183 26		231 24	140 45		241 19		119 10		93 03	40	
20	185 56		233 54	143 15		243 49		121 41		95 29	39	
30	188 26	· ·	236 25	145 45	· ·	246 19	· ·	124 11	· ·	97 54	· 38	
40	190 56		238 55	148 15		248 49		126 41		100 19	37	
50	193 26		241 26	150 45		251 19		129 12		102 45	36	
1 00	195 56	N17 52	243 56	153 15	N25 41	253 49	S 6 03	131 42	N22 18	105 10	N15 35	
10	198 26		246 26	155 44		256 20		134 12		107 36	34	
20	200 56		248 57	158 14		258 50		136 43		110 01	33	
30	203 26	· ·	251 27	160 44	· ·	261 20	· ·	139 13	· ·	112 26	· 32	
40	205 56		253 58	163 14		263 50		141 43		114 52	31	
50	208 26		256 28	165 44		266 20		144 14		117 17	30	
2 00	210 56	N17 52	258 58	168 14	N25 41	268 50	S 6 02	146 44	N22 18	119 43	N15 29	
10	213 26		261 29	170 44		271 20		149 14		122 08	28	
20	215 56		263 59	173 14		273 50		151 45		124 33	27	
30	218 26	· ·	266 30	175 43	· ·	276 21	· ·	154 15	· ·	126 59	· 26	
40	220 56		269 00	178 13		278 51		156 45		129 24	24	
50	223 26		271 31	180 43		281 21		159 16		131 49	23	
3 00	225 56	N17 53	274 01	183 13	N25 41	283 51	S 6 01	161 46	N22 18	134 15	N15 22	
10	228 26		276 31	185 43		286 21		164 16		136 40	21	
20	230 56		279 02	188 13		288 51		166 47		139 06	20	
30	233 26	· ·	281 32	190 43	· ·	291 21	· ·	169 17	· ·	141 31	· 19	
40	235 56		284 03	193 13		293 51		171 47		143 56	18	
50	238 26		286 33	195 43		296 22		174 18		146 22	17	
4 00	240 56	N17 54	289 03	198 12	N25 41	298 52	S 6 00	176 48	N22 17	148 47	N15 16	
10	243 26		291 34	200 42		301 22		179 19		151 13	15	
20	245 56		294 04	203 12		303 52		181 49		153 38	14	
30	248 26	· ·	296 35	205 42	· ·	306 22	· ·	184 19	· ·	156 03	· 13	
40	250 56		299 05	208 12		308 52		186 50		158 29	11	
50	253 26		301 35	210 42		311 22		189 20		160 54	10	
5 00	255 56	N17 54	304 06	213 12	N25 41	313 52	S 6 00	191 50	N22 17	163 20	N15 09	
10	258 26		306 36	215 42		316 23		194 21		165 45	08	
20	260 56		309 07	218 11		318 53		196 51		168 10	07	
30	263 26	· ·	311 37	220 41	· ·	321 23	· ·	199 21	· ·	170 36	· 06	
40	265 56		314 07	223 11		323 53		201 52		173 01	05	
50	268 26		316 38	225 41		326 23		204 22		175 27	04	
[illegible]												
6 00	270 [illegible]		[illegible]	[illegible]		[illegible]	S 5 59	206 52	N22 17	177 52	N15 [illegible]	

Alt. ° | Corr. +′

Portions of the right-hand pages of the American Air Almanac (above), British (top left), French (top right), and German (lower right) air almanacs.

Ed. Note: This article is based on a lecture delivered to the American Astronomical Society, at New Haven, Conn., June 14, 1942.

L MANACS

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veg, U. S. Navy, Supt., U. S. Naval Observatory

advantage of the fact that the stars have comparatively fixed relative positions. In these the altitudes and azimuths of a few selected stars are given directly as functions of the latitude and local hour angle; some use local hour angle of the individual star and some that of the vernal equinox. It is necessary to correct for the small annual changes in the positions of the stars.

In navigation, as in any other computing problem, a compromise must be made between the desire to use general, uniform methods of procedure, and the temptation to take advantage of the short cuts possible for special cases.

Local hour angle is a linear combination of several quantities which may be combined in various orders, most of which have been recommended on many occasions. While there are variations even in this detail, the customary procedure has been to determine the Greenwich hour angle and from it to subtract the longitude.

The following four methods are commonly used to determine the Greenwich hour angle:

$$\begin{aligned} \text{GHA} &= (\text{GHA v. e.}) - (\text{RA}) \\ &= (\text{GHA v. e.}) + (-\text{RA}) \\ &= \text{GCT} + \\ &\quad (\text{GHA v. e.} - \text{GCT} - \text{RA}) \\ &= (\text{GHA v. e.} - \text{RA}) \end{aligned}$$

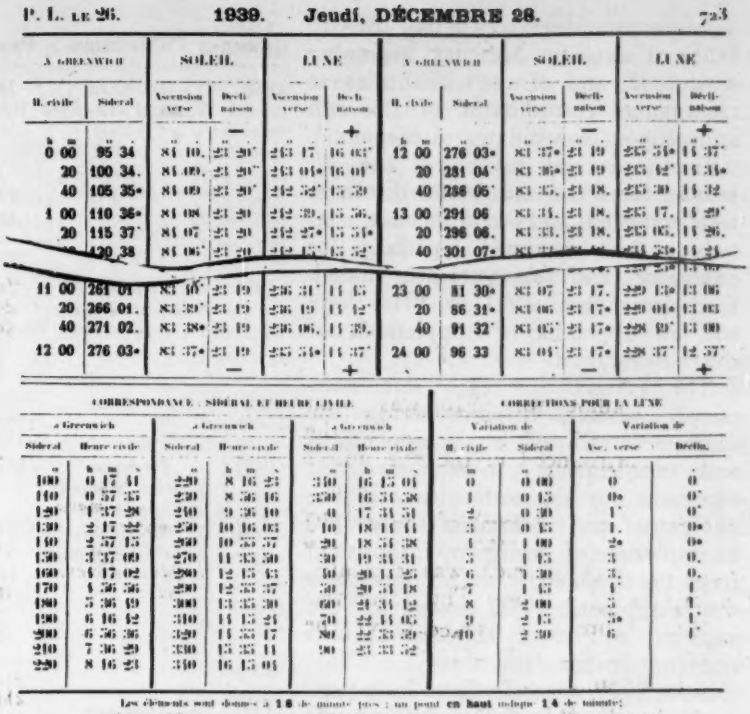
where the quantities in parentheses are tabulated in the almanacs with the Greenwich civil time (GCT) as argument. (GHA v. e.) is commonly called sidereal time, (RA) right ascension, (—RA) versed ascension or sidereal hour angle, and (GHA v. e. — GCT — RA) equation of time. The last equation refers to the direct tabulation of Greenwich hour angle. Sidereal timepieces have occasionally been used to indicate GHA v. e. directly.

Additional variations in method arise from the fact that civil activities run according to civil time in hours, whereas nautical charts use degrees for latitude and longitude. The conversion from time to arc may be made with the aid of a table, by the use of a timepiece graduated in degrees, or by incorporating the conversion in the tabular data.

The problem facing the makers of nautical and air almanacs has been to enable the navigator to obtain declination and Greenwich hour angle in the time at his disposal, with due consideration of his training and of the economic factors involved.

In order to show the present *American Air Almanac* in the proper background, an outline of the history of the *American Nautical Almanac* and of the previous air almanacs is needed.

The first volume of the *American Ephemeris and Nautical Almanac* was that for 1855, and parts of the volumes from 1858 to 1910 were reprinted as the *American Nautical Almanac*. The volumes for these years were almost identical and contained about 270 pages. The principal changes during that interval were the



P. L. LE 26. 1939. Jeudi, DÉCEMBRE 28. 723

A GREENWICH	SOLEIL		LUNE		A GREENWICH	SOLEIL		LUNE	
H. civile	Sidéral	Ascension verse	Déclinaison	Ascension verse	Déclinaison	H. civile	Sidéral	Ascension verse	Déclinaison	Ascension verse	Déclinaison
		—		+				—		+	
h m	° ′	° ′	° ′	° ′	° ′	h m	° ′	° ′	° ′	° ′	° ′
0 00	95 34	81 10.	23 20'	243 17	16 01'	12 00	276 03•	81 37•	23 19	235 34•	15 37'
20	100 34.	81 09.	23 20'	243 01•	16 01'	20	281 04'	81 36•	23 19	235 42'	15 34•
40	105 35•	81 09	23 20'	242 52'	15 59	40	286 05'	81 35.	23 18.	235 30	15 32
1 00	110 36•	81 08	23 20	242 39.	15 56.	13 00	291 06	81 34.	23 18.	235 17.	15 29'
20	115 37'	81 07	23 20	242 27•	15 54•	20	296 06.	81 33.	23 18.	235 05.	15 26.
40	120 38	81 06'	23 20	242 15'	15 52'	40	301 07•	81 [illegible]	[illegible]	[illegible]	15 23•
[illegible]											
11 00	261 01	81 10'	23 19	236 31'	14 45	23 00	81 30•	81 07	23 17.	229 13•	13 06
20	266 01.	81 39'	23 19	236 19	14 42'	20	86 31•	81 06	23 17•	229 01•	13 03
40	271 02.	81 38•	23 19	236 06.	14 39.	40	91 32'	81 05'	23 17•	228 49'	13 00
12 00	276 03•	81 37•	23 19	235 54•	14 37'	24 00	96 33	81 04'	23 17•	228 37'	12 57'
		—		+					—		+

CORRESPONDANCE : SIDÉRAL ET HEURE CIVILE

à Greenwich		à Greenwich		à Greenwich		CORRECTIONS POUR LA LUNE			
Sidéral	Heure civile	Sidéral	Heure civile	Sidéral	Heure civile	Variation de H. civile	Variation de Sidéral	Variation de Asc. verse	Variation de Décln.
°	h m s	°	h m s	°	h m s	m	′	′	′
100	0 17 41	200	8 16 25	300	16 15 09	0	0 00	0	0
110	0 57 35	210	8 56 16	310	16 54 58	1	0 15	0•	0'
120	1 37 28	220	9 36 10	40	17 34 51	2	0 30	1'	0'
130	2 17 22	230	10 16 03	10	18 14 44	3	0 45	1.	0•
140	2 57 15	240	10 55 57	20	18 54 38	4	1 00	2•	0•
150	3 37 09	250	11 35 50	30	19 34 31	5	1 15	3	0.
160	4 17 02	260	12 15 43	40	20 14 25	6	1 30	3.	0.
170	4 56 56	270	12 55 37	50	20 54 18	7	1 45	4'	1
180	5 36 49	280	13 35 30	60	21 34 12	8	2 00	5	1
190	6 16 42	290	14 15 24	70	22 14 05	9	2 15	5•	1'
200	6 56 36	300	14 55 17	80	22 53 59	10	2 30	6	1'
210	7 36 29	310	15 35 11	90	23 33 52				
220	8 16 23	320	16 15 04						

Les éléments sont donnés à 10 de minute près ; un point en haut indique 10 de minute; un astérisque, 12 minute; un point en bas, 34 de minute; fractions à ajouter au chiffre des minutes.

Donnerstag, 28. Dezember 1939

M. G. Z.	Greenwicher Zeitwinkel													
	Sonne ☉		Venus ♀		Mars ♂		Jupiter ♃		Saturn ♄		Mond ☾		Widderp. ♈	
Mittern.	359°	45′	329°	30′	279°	45′	274°	24′	252°	0′	158°	51′	275°	34′
20′	19	44	349	29	299	46	294	27	272	4	178	5	295	37
40	39	44	9	28	319	47	314	30	292	7	197	19	315	40
60	59	43	29	27	339	48	334	33	312	10	216	33	335	44
[illegible]														
320	319	38	289	13	240	5	235	11	212	53	106	40	236	26
340	339	38	309	12	260	6	255	14	232	56	125	55	256	30
Mittern.	359	37	329	11	280	7	275	17	252	59	145	10	276	33

M.G.Z.	Einschaltwerte für Greenwicher Zeitwinkel						
	Sonne ☉	Venus ♀	Mars ♂	Jupiter ♃	Saturn ♄	Mond ☾	Widderp. ♈
1′	1′ 0′	1′ 0′	1′ 0′	1′ 0′	1′ 0′	0′ 58′	1′ 0′
2	2 0	2 0	2 0	2 0	2 0	1 55	2 0
3	3 0	3 0	3 0	3 0	3 0	2 53	3 0
4	4 0	4 0	4 0	4 1	4 1	3 51	4 1
[illegible]							
17	17 0	16 59	17 1	17 3	17 3	[illegible]	17 3
18	18 0	17 59	18 1	18 3	18 3	17 19	18 3
19	19 0	18 59	19 1	19 3	19 3	18 17	19 3

M. G. Z.	Abweichung													
	Sonne ☉		Venus ♀		Mars ♂		Jupiter ♃		Saturn ♄		Mond ☾		Änd. je 1	
Mittern.	23°	20′ S	21°	5′ S	2°	17′ S	0°	55′ S	7°	4′ N	16°	3′ N	0.4	
40′			21	3	2	15					15	45	0.5	
80	23	20	21	2	2	14	0	55			15	27	0.5	
120	23	19 S	21	0 S	2	12 S	0	54 S	7	4 N	15	8 N	0.5	
160			20	58	2	10			7	5	14	47	0.5	
200	23	19	20	56	2	8					14	27	0.5	
240	23	18 S	20	54 S	2	6 S	0	54 S			14	5 N	0.6	
280			20	52	2	4	0	53			13	43	0.6	
320			20	50	2	2					13	20	0.6	
Mittern.	23	18 S	20	48 S	2	0 S	0	53 S	7	5 N	12	57 N		

Halbm d. S. ⊙ ρ = 16′

Mittlere Ortszeit des Sonnen- und Mond-Auf- und -Untergangs (Mond für 0° Länge)						
Breite	10° S	10° N	30° N	40° N	50° N	60° N	70° N
Sonnenaufgang	5h 40m	6h 15m	6h 54m	7h 21m	7h 58m	9h 4m	—
Sonnenunterg.	18 22	17 48	17 8	16 42	16 5	14 59	—
Dauer d. Dämm.	0 36	0 36	0 41	0 47	0 58	1 25	Anf. 9h 56m Ende 15 5
Mondaufgang	20 22	20 1	19 38	19 23	19 2	18 28	17h 15m
Monduntergang	7 30	7 53	8 19	8 36	8 59	9 35	10 53
Aufg. Änd. f. 10°	−1	−2	−2	−2	−2	−2	−3
Untg. O-Länge	−2	−2	−1	−1	−1	−1	0

Halbm. d. M. ☾ ρ = 16′
Parallaxe d. M. ☾ π = 60′

inclusion of tide tables from 1864 to 1868, of data on Mercury beginning with 1882, and of such quantities as rectangular co-ordinates of the sun and ecliptic co-ordinates of the moon.

In the second edition of the *Almanac* for 1910, the lunar distances were omitted and an appendix containing data arranged especially for navigators and surveyors was added. Each year from 1911 to 1915 there was an appendix or supplement of this nature.

The volume for 1916 was completely revised to incorporate the changes introduced in the appendices and supplements. It was designed especially for the convenience of the navigator and contained only 130 pages, none of which was reprinted from the *Ephemeris*. This form was continued until 1931, except for the addition in 1919 of 32 pages of sunrise and similar data.

Since 1929, several efforts have been made in the American almanac office to facilitate the work of the aerial navigator by doing more of the computing for him. The resulting publications include the *Aeronautical Supplement* for September, 1929, to December, 1930; the *Supplement* for 1931; the revised *Nautical Almanac* for 1932; the *Air Almanac* for 1933; the revised *Nautical Almanac* for 1934 and 1936; and the *Air Almanac* for 1941 to date. The total number of pages published annually has increased from the 130 of the *Nautical Almanac* for 1916 to the 320 of the present *Nautical Almanac* and 730 of the *Air Almanac*.

Between the publication of the *American Air Almanac* for 1933 and that for 1941, publication of air almanacs was started by Germany, France, and Great Britain. The German almanacs for 1935 and 1939, the French almanac for 1936, and the British almanac for 1939 each contains 730 pages, while the British and German almanacs for 1937 contain 365.

There has been considerable variety in the several almanacs not only in the method of obtaining the Greenwich hour angle and in the accuracy and tabular interval of the data, but also in the general arrangement. The 1916 *American Nautical Almanac* had a section for each object which contained all the data for the entire year. The previous ones followed this scheme for the planets, but had monthly sections each containing subsections for sun, moon and lunar distances. The present one has annual sections for all objects except the stars, which are arranged in monthly sections. The present British nautical almanac has monthly sections with subsections for sun, moon, planets, and stars; the times of sunrise and similar data are contained in separate annual sections. The German air almanac for 1935 seems to have been the first to use a daily sheet with all the data for a single day, though this form of almanac had previously been recommended in this country. The 1936 French air almanac employed the daily sheet, and the British and German for 1937 had a sheet for each two days. The present American, British, French, and German[1] air almanacs use the daily sheet. The British, French, and German almanacs have separate sections on the sheet for different quantities, whereas the American has all the ephemeral data arranged in parallel columns with a single argument and a single method of interpolation, and with the two coordinates of an object always adjacent to each other.

The contents of the various almanacs are shown in the accompanying table.

The accompanying illustrations show portions of sample daily pages from the American, British, French, and German air almanacs. Note that all except the French give the nearest minute of arc only and all except the German use Greenwich civil time in hours. The French and the American have the two co-ordinates of an object always adjacent to each other and the German and the American have a single tabular interval.

The American almanac uses the shortest tabular interval for all the

Year	Publication	Pages	Object	Data		Accuracy			Tabular Interval
1858	*American Nautical Almanac*	24	Sun	RA	Dec. Eq.	0s.01	0″.1	0s.01	1 day
		108	Moon	RA	Dec.	.01	.1		1 hour
		24	Planets (4)	RA	Dec.	.01	.1		1 day
		2	V. Equinox	GHA		.01			1 day
		3	Stars	RA	Dec.	.01	.1		1 year
		72	Lunar Dist.						
		46	Misc.						
		279							
1916	*American Nautical Almanac*	24	Sun	Eq.	Dec.	0s.1	0′.1		2 hours
		46	Moon	RA	Dec.	1.	.1		2 hours
		16	Planets (4)	RA	Dec.	1.	.1		1 day
		2	V. Equinox	GHA		.1			1 day
		2	Stars	RA	Dec.	.1	.1		1 month
		40	Misc.						
		130							
1930	*American Nautical Almanac Supplement*	365	Moon	GHA	Dec.	0′.1	0′.1		10 minutes
1931	*American Nautical Almanac Supplement*	24	Sun	Eq.	Dec.	0s.1	0′.1		2 hours
		92	Moon	RA	Dec. GHA	1.	.1	0′.1	1 hour
		16	Planets (4)	RA	Dec.	1.	.1		1 day
		2	V. Equinox	GHA		.1			1 day
		2	Stars	RA	Dec.	.1	.1		1 month
		78	Misc.						
		214							
1932	*American Nautical Almanac*	214	*Same as Supplement for 1931.*						
1933	*American Air Almanac*	24	Sun	GHA	Dec.	0′.1	0′.1		1 hour
		122	Moon	GHA	Dec.	.1	.1		10 minutes
		12	Planets (4)	GHA	Dec.	.1	.1		1 day
		24	Stars	GHA	Dec.	.1	.1		1 day
		30	Misc.						
		212							
1934	*American Nautical Almanac*	36	Sun	Eq.	Dec. GHA	0s.1	0′.1	0′.1	2 hours
		92	Moon	RA	Dec. GHA	1.	.1	.1	1 hour
		16	Planets (4)	RA	Dec. GHA	1.	.1	.1	1 day
		2	V. Equinox	GHA		.1			1 day
		4	Stars	RA	Dec. GHA	.1	.1	.1	1 month
		88	Misc.						
		238							
1936	*American Nautical Almanac*	48	Stars	GHA	Dec.	0′.1	0′.1		1 day
		244							
		292							
1938	*American Nautical Almanac*	12	Misc.						
		292							
		304							
1939	*American Nautical Almanac*	14	Misc.						
		304							
		318							

[1]The author has been unable to determine definitely that the German Air Almanac is still of the same form as that of 1939.

Year	Publication	Pages	Object	Data		Accuracy		Tabular Interval
1935	*German Air Almanac*	730	Sun	Eq.	Dec.	1′.	1′.	30 degrees
			Moon	Eq.	Dec.	1.	1.	15 degrees
			Planets (4)	Eq.	Dec.	1.	1.	30 degrees
			Stars (15)	Eq.	Dec.	1.	1.	15 degrees
1936*	*French Air Almanac*	730	V. Equinox	GHA		1/4′		20 minutes
			Sun	SHA	Dec.	1/4	1/4′	20 minutes
			Moon	SHA	Dec.	1/4	1/4	20 minutes
			Venus	SHA	Dec.	1/4	1/4	20 minutes
			Mars	SHA	Dec.	1/4	1/4	20 minutes
			Jupiter	SHA	Dec.	1/4	1/4	2 hours
			Saturn	SHA	Dec.	1/4	1/4	2 hours
			Stars	SHA	Dec.	1/4	1/4	1 month
1937	*British Air Almanac*	365	V. Equinox	GHA		1′.		10 minutes
			Sun	GHA	Dec.	1.	1′.	1 hour
			Moon	GHA	Dec.	1.	1.	1 hour
			Planets (4)	GHA	Dec.	1.	1.	6 hours
			Stars	SHA		1.	1.	2 days
1937	*German Air Almanac*	365	V. Equinox	GHA		1′.		20 degrees
			Sun	GHA	Dec.	1.	1′.	20 degrees
			Moon	GHA	Dec.	1.	1.	20 degrees
			Planets (4)	GHA	Dec.	1.	1.	20 degrees
			Stars	SHA	Dec.	1.	1.	1 month
1939	*British Air Almanac*	730	V. Equinox	GHA		1′.		10 minutes
			Sun	GHA	Dec.	1.	1′.	10 minutes
			Moon	GHA	Dec.	1.	1.	10 minutes
			Planets (3)	GHA	Dec.	1.	1.	1 hour
			Stars	SHA	Dec.	1.	1.	3 months
1939	*German Air Almanac*	730	V. Equinox	GHA		′.		20 degrees
			Sun	GHA	Dec.	1.	1′.	20 degrees
			Moon	GHA	Dec.	1.	1.	20 degrees
			Planets (4)	GHA	Dec.	1.	1.	20 degrees
			Stars (16)	GHA	Dec.	1.	1.	20 degrees
1941	*American Air Almanac*	730	V. Equinox	GHA		1′.		10 minutes
			Sun	GHA	Dec.	1.	1′.	10 minutes
			Moon	GHA	Dec.			10 minutes
			Planets (3)	GHA	Dec.	1.	1.	10 minutes
			Stars	SHA	Dec.	1.	1.	4 months

*Accuracy of 1′ through 1938, 1/4′ since 1939.

data, to facilitate interpolation.[2] While there are more figures on the American page, the arrangement of the data is such that the correct figure is located with little effort.

The *American Air Almanac* is prepared by a unique method, developed in the Nautical Almanac Office, whereby the human element has been almost entirely eliminated. Automatic computing machines using punched cards not only perform the calculations but print the results in such form that they can be reproduced directly by the photo-offset process. Thus all the conventional methods of computation and typesetting have been eliminated. The pages come from the machines practically perfect, but as an added precaution they are checked by the automatic process described in the next paragraph.

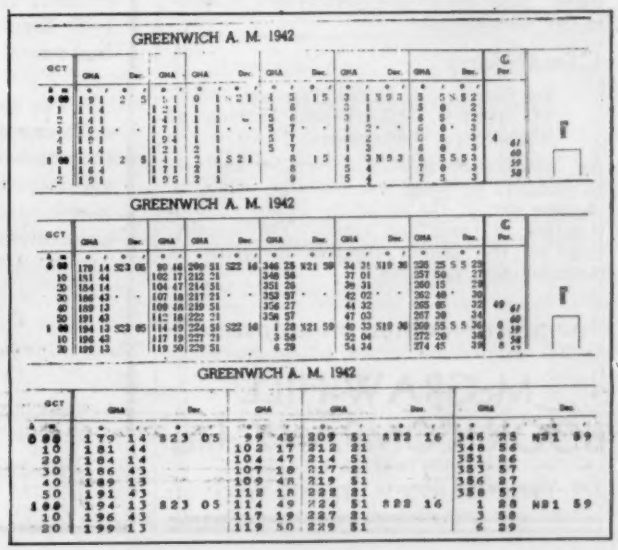
In the case of the *Nautical Almanac* the calculation is performed automatically on the machines and the printer's copy is prepared automatically from the cards. The figures are still being set in type but proofreading in the ordinary sense is a thing of the past. When the proof comes from the printer it is punched on cards without reference to the copy. These cards are then compared automatically with the cards from which the printer's copy was prepared. Finally the columns of figures are automatically differenced on the machines. The efficiency and accuracy of this method are revolutionary.

Tabular matter prepared on accounting machines had previously been reproduced for limited use, but not in cases where compactness and legibility were as important as in the *Air Almanac*. The printing device on an accounting machine was designed for speed and accuracy rather than for elegance in the appearance of the record. The figures are not only inferior to printed figures in alignment and uniformity, but are spread out in such a way that the page is very bulky. The figures on an accounting machine are about as tall as ordinary 10-point type but they are printed six to the inch in the line, whereas printed figures of the same size are about 12 to the inch.

In the process developed in the Nautical Almanac Office these difficulties have been largely overcome, and the pages of the *Air Almanac* are of such high quality that the casual reader doesn't even notice that they were not printed from type. The method required no fundamental alteration of the printing mechanism. It did require, however, a special type face, special platen spacing, and careful examination of each of the many features entering into the printing, such as paper, ink, humidity, and machine adjustment. There is little doubt that in the course of a few years facilities for producing even better records from punched cards will be developed, but the method now in use has made it possible to adopt this revolutionary procedure without waiting for elaborate engineering development and without draining engineering talent from other phases of the war effort.

The printing of 12 figures to the inch in the line instead of six is accomplished by printing the page in two successive runs of the form through the machine. On the first run, alternate figures in each line are printed, six to the inch, by using all the type bars. The carriage is then moved half a space, and on the second run the missing figures are filled in on the half space. The accompanying illus-

(Continued on page 17)



The appearance of a page from the American Air Almanac: after first run (top), after second run (center), after single run on a standard machine (bottom).

[2]Beginning with 1944 the British air almanac uses the 10-minute interval.

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By BERNHARD HAURWITZ and JAMES M. AUSTIN. Massachusetts Institute of Technology. 407 pages. $4.50.

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BOOKS AND THE SKY

GEOLOGY APPLIED TO SELENOLOGY

The Imbrian Plain Region of the Moon

J. E. Spurr. The Science Press, Lancaster, Pa., 1944. 112 pages. $3.00.

AS the subtitle to this book suggests, only one portion of the moon's surface is treated, although there are occasional references to features outside the region. There are four plates and 24 figures illustrating the text. The print itself is easy to read (although there are several obvious typographical errors) and the book is technically a good job of printing and binding.

With these mechanical details disposed of, it is with some trepidation that I approach the subject matter. I know of another very famous geologist (for that is Mr. Spurr's profession) who disapproves of most geological attacks on the lunar formations, whereas I have committed myself to approval of anything that smacks of normal igneous activity, in order to avoid the meteoritic impact hypothesis.

Mr. Spurr writes as a geologist: the reader must learn the vocabulary e[illegible] by browsing through other books, or by clever deduction, trusting the etymology for most of the words. This, coupled with the wealth of intimate detail discussed in the work, forbids reading for an hour's light pleasure. The material must be read carefully, digested and then read again, before any opinions are formulated. To the few vigorous proponents of the meteor-crater hypothesis the book will be most irritating, for the only mention of that idea is a two-page **addendum** at the very end, in which some very concise statements are made, for instance:

"To the speculation that meteoric fall may have been more abundant in the past may be opposed the counter-speculation that it may have been less . . ." and, in a quotation from W. W. Campbell: "The unquestioned existence of craterlets in the summits of central crater peaks is absolutely fatal to the impact theory of the origin of those peaks . . ."

Perhaps the most positive touch of all is a quotation from Proctor (who in 1873 began talking about the meteoric hypothesis) that indicates very conclusively that by 1888 he had abandoned any idea of the meteoric origin.

Mr. Spurr does it all with gas, bub[illegible] through the molten surface of [illegible]th increasing difficulty until [illegible]s crust having begun to form, craters were produced. Faults were formed, as they have been on the earth, and along those lines the gases found their way out; there are many

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aligned sets of similar craters in various portions of the moon. Whatever the origin of such chains of craters, it is far too good shooting for meteorites!

Perhaps there are some who would be pleased if magma or molten rock were substituted for Mr. Spurr's gas; I would, as I have stated elsewhere. Then there are those who will let us have gas, magma, hot water, or anything else, if we'll just forbid any independent action by these agencies—despite their abundant action on the earth—if we'll just let a little meteorite or two punch the hole so the stuff can well up and form the crater.

There are some current books by gentlemen who apparently have never looked at the moon through a telescope, for the statement is made that there is no evidence for any lava flows on the moon. Spurr points out many obscure ones, in addition to the obvious flows that can be picked out on almost any photograph. Can anyone doubt that the moon has some features formed by action we call geological, if a geologist can write upwards of 40,000 words on the subject, confining himself to less than an eighth of the area of the visible hemisphere?

Certainly this is not the hypothesis in its original form, although it is close to it. Mr. Spurr's contribution is chiefly in his detailed pointing out of interesting little features that have escaped most other observers. Even if all his conclusions should be wrong, his description of the Mare Imbrium region poses more awkward problems for those who want to do it by impact, meteoritic or otherwise.

ROY K. MARSHALL
Fels Planetarium

NEW BOOKS RECEIVED

A Comet Strikes the Earth, *H. H. Nininger*, 1942, *American Meteorite Laboratory*, Denver, Colo. Unpaged. 35 cents.

Several pages of text and a number of new illustrations have been added in the new edition of this pamphlet on meteorites. A specimen of Meteor Crater iron is cleverly incorporated into each booklet.

A Dipper Full of Stars, *Lou Williams*, 1944, *Follett*. 170 pages. $2.00.

Subtitled *A Beginner's Guide to the Heavens*, this is a book prepared on junior high school level; the subject is approached from an observational point of view.

The Universe Around Us, *Sir James Jeans*, fourth edition 1944, *Macmillan*. 297 pages. $3.75.

The fourth edition of this well-known book has been completely revised and reset.

Men of Science in America, *Bernard Jaffe*, 1944, *Simon and Schuster*. 600 pages. $3.75.

As the subtitle indicates, this is a book on the role of science in the growth of our country, woven around stories of the lives of 19 of our outstanding scientists, past and contemporary.

AIR ALMANACS

(Continued from page 15)

tration shows the form after the first and second runs on the machine. Shown at the bottom of the same illustration is a portion of the same page as it would appear if prepared on a standard machine.

There is always the general question of revising nautical almanacs and air almanacs. Naturally, the staff of the Nautical Almanac Office devotes a great deal of thought not only to detailed improvement but also to the more general question of the ideal almanac. Many suggestions are received from others interested in navigation; from Army, Navy, and commercial pilots, from officers in the Navy and Merchant Marine, from instructors of navigation, and from amateurs.

Decision on which improvements to adopt and when to adopt them is difficult and can be made only on the basis of all the factors involved, and in accordance with a consistent long-range policy. The almanacs cannot be used lightly for experimentation or to reflect personal whims. Each modification must be examined not only for intrinsic worth, but also for consistency with the almanac as it exists or is planned for the future. The saving brought about by an alteration must more than offset the inconvenience caused by the change.

This last point is frequently underestimated. It must be remembered that any change in one of these almanacs may require each of over 50,000 users to revise his habits. While these changes look simple to one who has studied the subject sufficiently to make a suggestion, it must be remembered that many capable navigators have had little academic training and find it difficult to study out a new method on the spur of the moment without instruction. These changes are particularly distasteful to the sea navigator who reduces only a few sights a day and would need to spend only a few minutes, even with the 1916 form of *Nautical Almanac*, to obtain the necessary astronomical data.

The present *American Air Almanac* was designed under very favorable circumstances. There had been enough aerial navigation to find out what was required of an almanac, and the aerial navigators were in general a small group of carefully selected and highly educated young men. It was therefore possible to make an almanac on the basis of what was then considered the ideal almanac without much regard to the past. This almanac has been most enthusiastically received and for the present, at least, seems quite adequate. There is now the additional factor that at least 50,000 people are familiar with it. Of course, aeronautics is moving rapidly and changes may become necessary.

There are many improvements which might be made in the *Nautical Almanac* to make it more convenient, especially if an increase in size were permitted. One obvious way is to make it more like the *Air Almanac*. However, since the *Air Almanac* is available whenever speed is essential, there is no urgent need for disturbing the *Nautical Almanac* until a more favorable time. There is one detail which has been changed in the 1944 *Nautical Almanac*, that is, the elimination of the approximate method of interpolating the moon's ephemeris. This feature had been for the use of aviators, who no longer use the book.

The question of whether there should be separate almanacs for sea and air navigation or a combination for both is a recurrent one. Before the present *Air Almanac*, the various publications brought out for aviators were in each case amalgamated with the *Nautical Almanac* for the succeeding year, with strong protest from those navigators who resented the continual revision of the *Nautical Almanac*. At the present time, the combination of the two publications would be very unwise, yet the situation may well change in a very few years.

The many suggestions which are submitted for improving the almanacs are much appreciated, and it is hoped that the fact that they cannot all be immediately adopted will not be considered as evidence that the suggestions are not wanted or that they will not eventually serve a useful purpose. All suggestions received are considered with respect to immediate adoption and are preserved for reference in connection with subsequent revisions.

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From Start to Finish

By ALLYN J. THOMPSON

I—THE NEWTONIAN REFLECTOR

THE first reflecting telescope, of the type so popular today, was made in 1672 by Sir Isaac Newton, equipped, so historians tell us, with a spherical mirror. How the mirror chanced to be finished spherical is not explained, as the test used today for spherical mirrors was unknown at that time. However that may be, no great success was had with it anyway. Fig. 2 shows how a spherical mirror fails to bring parallel rays to a single focus. Rays reflected from the center of the mirror are brought to focus farther away than rays from the outer zones.

From a study of the diagram we might conclude that if the center of the mirror were properly deepened, that is, given a shorter radius, or if the radii of the outer zones were lengthened, or if a little of each were done, all of the reflected rays could be brought to a common focus. That is a practical solution, and the resulting surface in each instance is a parabola of revolution, or a paraboloid. (See Fig. 19.) The standard practice is to deepen the sphere at the center so that, for a 6-inch f/8 mirror, the radius there is about .1" shorter than it is at the edge zone. The amount of glass removed in this operation is of the order of one half a wave length of light in thickness, about .00001", and, incredible as it may seem, represents the difference between poor and good performance.

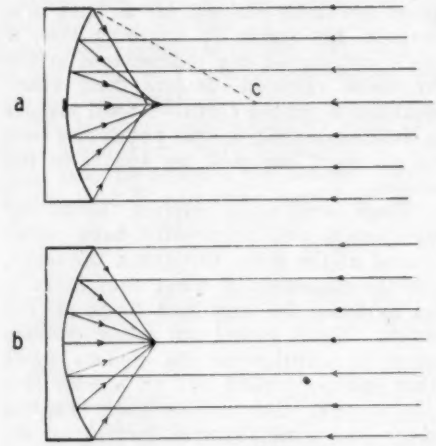


Fig. 2. Reflection of parallel rays from: a, a spherical mirror; b, a parabolic mirror. On this scale, our 6-inch f/8 mirror is shown by the short heavy line in a.

Early mirrors were made of speculum metal, an alloy of copper and tin, which could be given a beautiful polish, but the amount of work involved in producing the speculum was tremendous. Following the discovery of a method for depositing silver on glass, about the

EDITORIAL COMMENT

WE have long appreciated the need for a discussion of amateur telescope making which would present, in logical sequence, details of a program for the fabrication of an objective mirror and its diagonal, the construction of its tube and mounting, and the collimation and erection of the complete instrument.

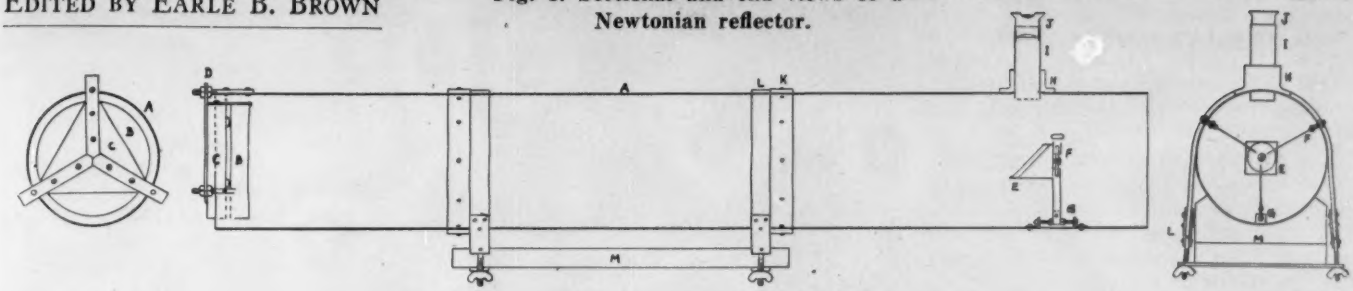
Mr. Thompson has fulfilled this need in a series of articles starting here, to be published in booklet form upon the completion of the series in these columns. We believe these articles are exactly what the new convert to telescope making requires: a standardized method for making a reflecting telescope.

There are those who may say that the techniques here described are not the best possible, but such critics will disagree as to what the best techniques are. Mirror making is a craft, and there are many ways to make a mirror. The methods described here are time-tested and reliable—no one will go wrong by following them. A new member of the telescope making fraternity will do well to forego all contemplation of advanced techniques of testing and figuring; to avoid all telescope designs (for his own) except the simple Newtonian; to ignore all tests except the old reliable Foucault knife edge, until he has completed his first mirror, mounted it in a tube, and spent at least a few pleasant hours looking at the celestial wonders his instrument will reveal. Having followed this plan, he may then feel free to turn to more involved and difficult designs and methods.

This description should enable the prospective worker to make his first reflecting telescope entirely by himself. However, a craft is not taught merely by laying down a set of printed rules—the written word can only guide the student toward the mastering of the craft by describing simple and effective ways in which the desired results can be achieved, and by pointing out the more obvious and natural pitfalls which cause trouble and discouragement.

We have known Mr. Thompson for a long time; he is one of the best amateur mirror makers. He has conducted the telescope making class of the Optical Division, Amateur Astronomers Association, at the Hayden Planetarium in New York for many years, and therefore knows at first hand the most common problems confronting the beginner in optics. The treatise was originally planned as a text for his class, but we are sure it will be of broader interest; a review of the methods it describes may also be found of value to the more advanced amateur telescope maker. E. B. BROWN

Fig. 1. Sectional and end views of a Newtonian reflector.



Shown at left and right are suggested designs for mirror cell and spider support. A, tube; B, mirror; C, cell; D, adjusting lock nuts; E, diagonal; F, spider support; G, 45° adjustment; H, adapter tube holder; I, adapter tube; J, ocular; K, position rings; L, retaining straps; M, saddle.

middle of the 19th century, annealed plate glass was used. The silver coating tarnished rapidly and frequent resilvering was necessary. Plate glass was troublesome because of its high coefficient of expansion, and the resulting ruinous effect on the figure caused by temperature changes. Since the rather recent development of pyrex glass, which has about one third the coefficient of expansion of plate glass, this trouble has been greatly reduced. Aluminizing, too, has almost entirely replaced silvering of mirrors.

Telescopes are usually designed to perform particular kinds of work. Some are meant to be used chiefly in photography. In general, for visual work, short focal ratios with their large fields are useful for comet seeking, variable star work, and the like. The longer ratios are used in planetary study, double star observations, and other fields where high powers and fine definition are required. Some of these instruments are portable, and others must be mounted on a solid pier. The amateur, however, usually has formulated no particular plan of observation. He wants to explore the heavens, and to see some of the wonders there that are forever hidden from the unaided eye.

From the experience gained by amateur telescope makers over a period of years, it has been found that the most practical and popular instrument for amateur use is the 6-inch f/8 Newtonian reflector. Its concave mirror is 6″ in diameter, with a focal length eight times that, or 48″. The delicate task of parabolizing the mirror, while not easy, is not beyond the ability of the careful worker. The 4-foot focal length makes for comfortable observing, and with a low-power ocular, the field of view is a trifle over one degree in diameter—more than twice that of the full moon. The magnifications that may be employed permit of a modest size of mounting, which can be made portable. Such a telescope will readily reveal stars of magnitude 12.5, as compared with the 6th-magnitude limit of the unaided eye, and the 9th-magnitude limit of the average binocular. Theoretically, it is capable of resolving double stars having a separation of .75 seconds of arc, but as magnifications exceeding about 30 per inch of aperture can seldom be used, we may not expect to separate doubles closer than 1.2 seconds of arc, and then only if the components are of nearly equal brightness. This telescope will show the divisions in Saturn's rings, many nebulae and clusters.

The purchase price of such an instrument of professional make is necessarily high, and many an amateur feels compelled to do without one. But if he is possessed of some ingenuity, is handy with tools, enjoys shaping wood and metal, and is willing to devote a few hours a week to the task, he can build the telescope himself, in its entirety, for a small fraction of that price.

In the following account the amateur astronomer will be introduced to the optician's art of grinding and polishing spherical surfaces on glass. He will learn how to alter the spherical surface to a paraboloid, an achievement that baffled the world's opticians for 50 years, from Newton to Hadley. He will learn how to test and figure an optically flat surface. He will find out how to make an equatorial mounting. He will take pride in his telescope, and derive profound pleasure from using it, because it will be a good one, and because he made it himself.

II — MATERIALS AND EQUIPMENT

Mirror Materials. A list of the materials and equipment which are necessary to produce the mirror follows:

A 6-inch pyrex mirror blank, from Corning Glass Co., Corning, N. Y.

A 6-inch plate glass tool, of a thickness at least ⅛ the diameter, from any plate glass manufacturer.

Abrasives: Carborundum, #80, 8 ounces; #120, 3 ounces; #220 and #400, 1 ounce each; #600 (or #11 emery), ½ ounce. #304 emery, ½ ounce; fine polishing rouge, 4 ounces.

Optical pitch, 1 pound; rosin, ½ pound; beeswax, 2 ounces. Most optical pitch is a refined pine tar product. When cold, it assumes a solid shape, but will flow under pressure. It usually has to be tempered with rosin or turpentine.

Kits containing the above materials are available from supply houses, or they can be bought separately from the manufacturers, or from jobbers. Carborundum: The Carborundum Company, Niagara Falls, N. Y. #11 emery, pitch, rosin, rouge: Universal Shellac Stick Co., Inc., 537 West Broadway, New York City. #304 emery, rouge: American Optical Company, Southbridge, Mass.

Also, a water pail, a bottle for water, such as a cruet, a coarse carborundum stone, a small paint brush from the 5 & 10 for applying the rouge, turpentine, paraffin, and a magnifying lens of about 1″ focal length. Also, pots, pans, and a hot plate for heating pitch and beeswax.

A template, channeling tool, grinding stand or barrel, Foucault testing device, a mirror rack, and stands for supporting these latter two.

The Template. This is used to gauge the curve on the mirror during the coarse grinding. We will give it a radius of curvature of 98 inches, although the finished mirror will have a radius of curvature of 96 inches. The template is best made from thin sheet metal, .006″ to .010″ thick. To cut the curve, first nail the sheet metal to the floor. Drill two holes in the ends of a long stick, 98″ apart, and nail one end to the floor so that the other end is free to swing across the metal sheet. Insert the point of a heavy knife into the hole at the free end, and cut through the metal in a single sweep. Examine the convex edge with the magnifier, and carefully file away all burrs. The template should be protected between two thin boards, with only its edge protruding. Since the difference of .001″ in

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the sagitta of our mirror means the difference of about one inch in focal length, great care must be exercised in its use. In using the template, watch carefully for any streaks of light visible between its edge and the mirror's surface.

The sagitta is the depth of the curve at the center, as measured between the surface of the mirror and a straight-edge laid across its diameter. It can be found from the formula, $r^2/2R$, where r is the radius of the mirror, and R its radius of curvature. For our 6-inch f/8 mirror, it is .047".

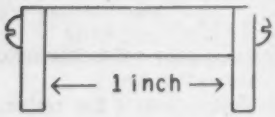


Fig. 3. Channeling tool in cross section.

Channeling Tool. This is used in forming the squares in the pitch lap, Fig. 13. It should be at least 8" long, with a cross-section like that in Fig. 3. A length of channel iron of those dimensions will do, or it may be made out of wood.

Grinding Stand. Considerable friction is encountered in polishing, so the grinding stand must be solid. A weighted barrel, with a reinforced top, will do. A stand like that shown in Fig. 4 is solid, cheap, and easily made. A 36" to 40" length of 2½" pipe, screwed into a heavy flange, is cast in a block of concrete. Another flange is fastened to the wooden top with lag screws, and screwed to the pipe base. A small cabinet in which to store the abrasives may be built in around the pipe.

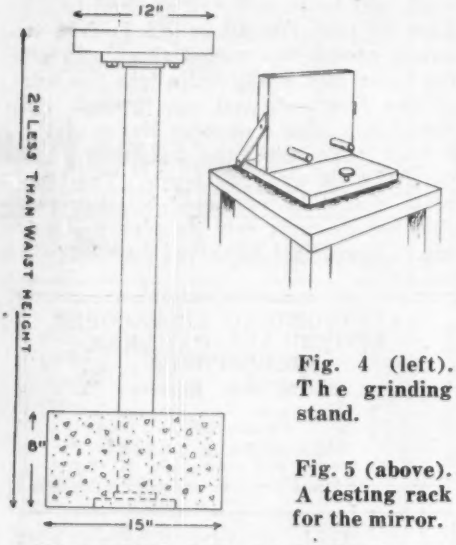


Fig. 4 (left). The grinding stand.

Fig. 5 (above). A testing rack for the mirror.

Mirror Rack. Fig. 5 shows a conventional form. The mirror is supported on two dowel sticks spaced about 4" apart. The rack rests on two "feet" at the back, and on the adjusting screw in front, which is used to tilt the mirror up or down.

Testing Stands. Measurements will have to be made in hundredths of an inch, so the testing stands must be sturdy, and rest solidly on the floor. Any vibrations which may result from passing trains or road traffic may sadly disrupt testing, so a concrete floor is preferred. If stands have to be built, they should be designed so that testing can be conducted in a comfortable sitting posture, and so that the center of the mirror, pinhole, and knife edge are at about the same level.

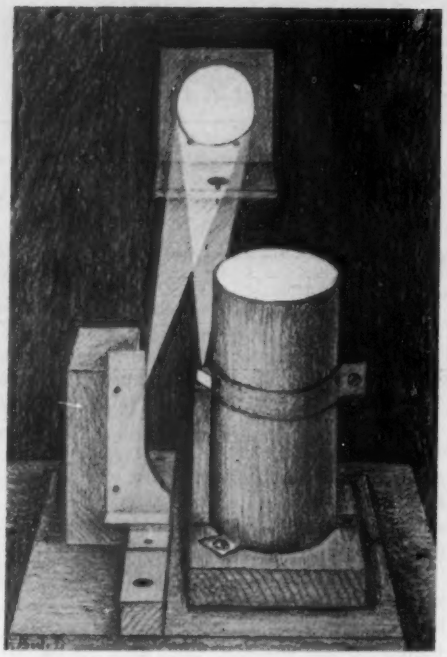


Fig. 6. Foucault's test. In this device a prism is used to bring the pinhole and knife edge into closer conjunction. "Artist's license" is used in this depiction; actually, the illumination is too feeble to render the cones of light visible. The pinhole sends out light (via the prism) in all directions over a much wider angle, but only the rays within the cone fall upon the mirror, about four per cent of which are returned by reflection to a focus at the knife edge. For minute control of the knife edge, apply downward pressure with the fingers at either of the X's, as suggested in the text.

Foucault Device. The requisites are: a light source, contained in an opaque shield in which there is a pinhole perforation, a knife edge, and a scale for making measurements. Fig. 6 illustrates a practical device. The baseboard is a flat well-seasoned board, such as ¾" plywood, about 6" x 9" in size. The guide cleat, a straight-edged stick 1" wide and 6" long, is attached to the baseboard about 2½" from one edge.

Fig. 7. The knife-edge scale, which should be made under a reading glass for greatest accuracy.

Fastened to this cleat in a suitable position is a strip of metal or plastic material on which has been scribed the scale shown in Fig. 7. The scale should be made under a reading glass for best accuracy. The horizontal lines are spaced .1" apart, and the vertical lines .2" apart. The diagonal lines divide the verticals into fiftieths of an inch. Interpolation can be made for readings of hundredths.

The knife edge, of rectangular shape, and having a perfectly smooth edge, is cut from a thin piece of sheet metal, and tacked to a block of wood about 1½" x 3" x 3" in size. If the lower part of the knife edge is cut, and bent at right angles, as in Fig. 6, and attached to the block so that this edge just skims the scale, it will also serve as the indicator. This indicator edge must be exactly parallel to the horizontal divisions of the scale when the block bears against the cleat.

For the light source, an ordinary 40- or 50-watt frosted lamp and socket are fastened to a 4" x 4" block of wood. A section of small stovepipe, or a tall can having both ends cut away, is set over the lamp. A "window," or hole about ⅛" in diameter is drilled into the side of the can at a height opposite the bright bulge of the lamp. A band of thin sheet metal, containing two or three pinholes of different sizes, is clamped around the can so that it can be slipped down over the window. Two pinholes, placed one above the other, about ¼" apart, will suffice. Thin an area of the metal band with emery paper until it is only a few thousandths of an inch thick; lay it on a piece of glass, and, twirling a needle between the fingers, pierce the first hole. Stop when the needle just breaks through, and examine the hole against the light with the magnifier. It must be perfectly round. Clean off the burrs with fine emery paper. For a finer hole, sharpen the needle on a fine stone, twirling and drawing it at the same time under the finger tip, until it appears perfectly sharp, viewed with the magnifier. Pierce the hole as before, but use less pressure.

To avoid discomfort from the heat of the lamp, and to bring the pinhole and knife edge into closer proximity, a small right-angle prism may be used. Instead of the window facing the mirror, turn the can 90° to the left, so that it faces the knife edge, and mount the prism as in the picture, on a block of wood, directly in front of the window or pinhole opening. A small chipped prism can be picked up for a few cents from dealers in secondhand novelties.

A great many refinements are often added in an effort to increase the efficiency of this device, including a very brilliant light source, condensing lenses, extremely small pinholes or an adjustable slit, and knife-edge motions controlled in two directions by micrometer screws. But the seemingly crude device described should enable the reader to produce a mirror capable of the finest possible definition.

(To be continued. Next month the theory of the Foucault test will be described and grinding will begin.)

DEEP-SKY WONDERS

AMONG marvels for observation in the November skies are the objects listed here. The informal descriptions give appearance in common telescopes. Norton designations are in parentheses.

Sculptor. NGC 253 (1^{5}), 0^{h} 45^{m}, —25° 34′; spiral galaxy. Large, fluffy, handsome in amateur telescopes. NGC 288 (20^{6}), 0^{h} 50^{m}, —26° 53′; globular. Same size as M13 in Hercules.

Triangulum. M33, 1^{h} 31^{m}, +30° 24′; spiral galaxy. Large, but very dim. M33 is a member of the group containing our own Milky Way system.

Lyra. M57, 18^{h} 52^{m}, +32° 57′; popular ring planetary.

Vulpecula. M27, 19^{h} 57^{m}, +22° 34′; Dumbbell planetary. Large, easy to find.

Aquarius. NGC 7009 (1^{4}), 21^{h} 01^{m}, —11° 35′; Saturn planetary.

L. S. COPELAND

STARS FOR NOVEMBER

from latitudes 30° to 50° north, at 10 p.m. and 9 p.m., war time, on the 7th and 23rd of the month, respectively. The 40° north horizon is a solid circle; the others are circles, too, but dashed in part. When facing north, hold "North" at the bottom, and similarly for other directions. This is a stereographic projection, in which the flattened appearance of the sky itself is closely reproduced, without distortion.

OBSERVER'S PAGE

All times mentioned on the Observer's Page are Eastern war time.

TITAN AND SOME ANOMALIES OF JUPITER IV

By JESSE A. FITZPATRICK

RECENTLY, an atmosphere was discovered on Titan, Saturn's brightest satellite, by Dr. Gerard Kuiper, of Yerkes Observatory, using the 82-inch McDonald telescope and attached spectrograph. This discovery suggests that a fruitful field of research in satellite atmospheres is afforded by the fourth satellite of Jupiter, long noted for its striking peculiarities.

Satellite IV (Callisto) is a large body, 3,145 miles in diameter, according to a measurement by Barnard, which would make it a trifle larger than the planet Mercury. The satellite's density, however, is estimated at only 0.6. This alone would suggest that it is either largely gaseous, or that it possesses an appreciable atmosphere which influences measurements of its apparent disk. As the disk is sometimes observed to be smaller than normal, and also occasionally to appear nebulous, an atmosphere is suggested. These particular phenomena occur independently of the satellite's position in its orbit.

Here are a few notes from the writer's observations of Jupiter IV:

Sept. 22, 1940. IV nebulous and ill-defined; color indeterminate. The disk of III, by comparison, sharp and distinct. All four bright satellites were visible, IV being brightest.

Oct. 9, 1940. IV, when only $5^h\ 15^m$ west of the same point in its orbit, was observed to be faintest of all four and to possess a sharply defined disk, distinctly ruddy.

Sept. 25, 1940. IV, east of Jupiter, was again nebulous and of grayish color, faintest of all.

Oct. 12, 1940. IV, $6^h\ 5^m$ east of the same point as on Sept. 25th, sharply defined but very faint; bluish.

Newcomb remarked that changes in the apparent brightness of all the Galilean satellites were "sometimes sudden in a surprising degree." This was strikingly demonstrated to the writer by a remarkable observation made on November 19, 1940.

The observation began at 7:45 p.m. E.S.T., IV being far east of Jupiter. It was remarkably faint and of an indeterminate color; III being brightest. As IV was so far from the planet, it was possible to examine it alone in the field. As thus seen it was so dull that III seemed twice as bright when viewed in the same way. Time out was taken to make a note of these facts, and III was then examined again in a solitary field, its magnitude being estimated at not far from Pickering's assigned value of 4.88.

Returning to a full-field view, including all of the satellites, IV was seen to have brightened suddenly until it was next to III in magnitude. To test for possible deception all of the satellites were thrown slightly out of focus, but the relative magnitudes held true. Next, IV was again examined alone in the field and it appeared bright and conspicuous. Moreover, the brightened disk was now nebulous whereas it had been sharp before. These singular changes took place within 15 minutes. Closely similar phenomena have been noted by various observers. Moreover, such changes appear to be related to apparent variations in the size of the satellite's disk.

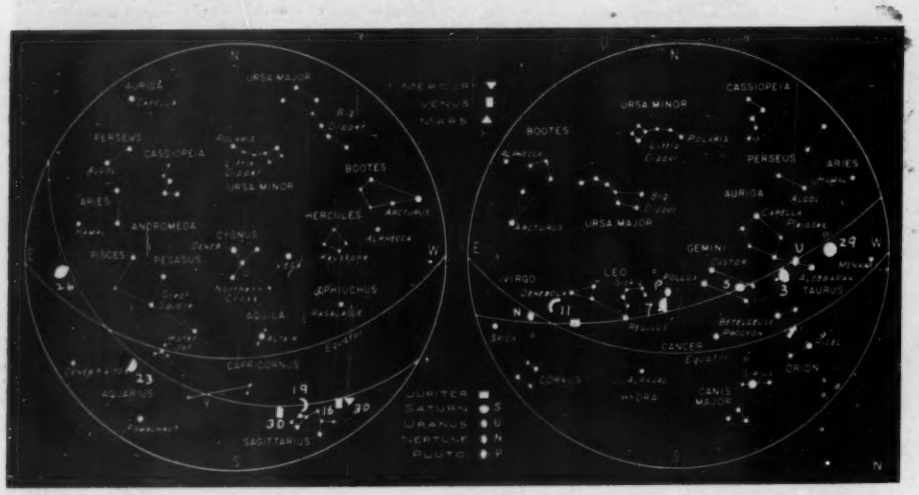
The true albedo (reflecting power) of IV appears to be low, and the actual surface to be remarkably dull (Young called Callisto "very dark complexioned"). How, then, to explain sudden changes which raise its albedo almost to that of III?

This observer believes that IV has an atmosphere occasionally clear and at other times cloud-laden. Clear atmosphere probably permits the actual dark surface to be seen and the satellite appears fainter and smaller. A highly reflective cloud, not necessarily covering the whole disk, might make it appear brighter and larger. Variations in the density of the satellite atmosphere would cause changes in the absorption at the limb, thus producing an occasional appearance of nebulosity.

At any rate, anyone possessed of suitable observing means and time will find a study of the fourth satellite of Jupiter an interesting program, and a pursuit which might well result in a real contribution to the problem of satellite atmospheres.

JAMES C. BARTLETT, JR.
Chairman, Astronomical Section,
American International Academy, Inc.

THE MOON AND PLANETS IN THE EVENING AND MORNING SKIES



In mid-northern latitudes, the sky appears as at the right at 6:30 a.m. on the 7th of the month, and at 5:30 a.m. on the 23rd. At the left is the sky for 6:30 p.m. on the 7th and for 5:30 p.m. on the 23rd. The moon's position is given for certain dates by symbols which show roughly its phase. Each planet has a special symbol, and is located for the middle of the month, unless otherwise marked. The sun is not shown, although at times it may be above the indicated horizon. Only the brightest stars are included, and the more conspicuous constellations.

Mercury, close to the sun most of the month, approaches eastern elongation and sets more than an hour after the sun at the end of the month.

Venus, in Ophiuchus and Sagittarius, is in the early evening sky. It will have a magnitude of —3.5 at the end of the month. On November 20th, it will be 9′ north of Lambda Sagittarii, the top star in the Archer's bow.

Mars is too near the sun for favorable observation throughout the month.

Jupiter, in Leo until November 15th, will then enter Virgo, rising about 2:30 a.m. in the middle of the month.

Saturn has entered the evening sky, crossing the meridian by 3:00 a.m. on the 30th of November. It is rapidly becoming a very favorable object for telescopic observations.

Uranus is in Taurus; **Neptune**, in Virgo; and **Pluto**, in Cancer.

VESTA'S POSITIONS

Vesta, the brightest of the minor planets, which often reaches naked-eye visibility, may be found in the following positions, taken from the **Handbook** of the British Astronomical Association:

1944	R.A.		Dec.		Mag.
U.T. 0^h	h.	m.	°	′	
Nov. 1	11	28.7	+8	05	8.1
11	11	45.0	6	41	8.0
21	12	00.9	5	22	7.9
Dec. 1	12	16.3	4	09	7.8
11	12	31.0	3	02	7.7
21	12	44.9	2	04	7.6
31	12	57.8	1	17	7.4

ANOTHER METEOR REPORT

Interest in the fireball over Indiana on August 18th still continues. Via Dr. Frank K. Edmondson, of Indiana University, we have received a report from L. A. Werner, of Detroit, Mich., who writes in part:

"At 8:10:30 a.m. on August 18, 1944, Mr. Walter Ward of the Palmer-Bee Company and I were approximately 7½ miles north of Marion, Ill., driving south on highway 37. The meteor first appeared at our left, 15° east of south and at an elevation of about 20°. The meteor had a round, white bubbly nose with a phosphorescent green and yellowish flame toward the outside extending back from it. The flame was very clear and with very little smoke—the tail was forked and faded into the blue of the sky. The duration of the burning stage was approximately 3½ to 4 seconds.

"The meteor's path was apparently parabolic for about ¾ of the distance; then, as it approached the horizon to the west, it seemed to curve sharply toward the earth, the flame having burned out . . . its course was some 45° off of our line of vision away from us. Inasmuch as we were riding about 10° west of south, I estimate the course of the meteor as west southwest or in that vicinity."

LEONIDS

The Leonid meteor shower will reach maximum about the 16th of November.

OCCULTATIONS FOR TEXAS

Predictions are for longitude 98° 0'.0 W., and latitude 30° 0'.0 N. The data include: date, name of star, magnitude; G.C.T. in hours and minutes, a and b quantities in minutes, and position angle, at immersion; G.C.T., a and b quantities, and P.A., at emersion.

Nov. 2, 193 B Tau, 6.3; 6:50.5, —1.2, +2.8, 32°; 7:59.4, —2.8, —0.6, 281°.

Nov. 2, Delta Tau, 3.9; 12:51.5, +0.1, +2.9, 132°; 13:30.7, —0.8, +1.2, 214°.

Nov. 2, 68 Tau, 4.2; 13:54.8, —0.3, 0.0, 60°; ....

Nov. 3, 351 B Tau, 6.2; 11:26.1, —1.5, —3.1, 130°; 12:21.2, —1.8, +1.5, 221°.

Nov. 22, BD —19° 6024, 6.8; 1:11.8, —0.9, +1.6, 29°; ....

Nov. 24, BD —11° 5997, 7.1; 5:05.0, —0.5, +0.8, 40°; ....

Nov. 25, BD —6° 6335, 6.8; 4:39.4, —5.4, —7.8, 134°; ....

MINIMA OF ALGOL

Nov. 1, 7:50 p.m.; 16, 7:54 a.m.; 19, 4:43 a.m.; 22, 1:32 a.m.; 24, 10:21 p.m.; 27, 7:10 p.m.

PHASES OF THE MOON

Last quarter ..	November 7,	2:28 p.m.
New moon	November 15,	6:29 p.m.
First quarter .	November 23,	3:53 a.m.
Full moon	November 29,	8:52 p.m.

OCCULTATIONS—NOVEMBER, 1944

Local station, lat. 40° 48'.6 north, long. 4h 55m.8 west.

Date	Mag.	Name	Immersion	P.*	Emersion	P.*
Nov. 2	6.3	193 B Tauri	3:52.2 a.m.	12°	4:36.0 a.m.	316°
3	6.2	351 B Tauri	7:36.9 a.m.	73°	8:38.3 a.m.	282°
7	6.1	139 B Cancri	0:23.7 a.m.	109°	1:22.6 a.m.	259°
21	6.8	BD —19° 6024	9:35.5 p.m.	36°		
23	7.2	BD —12° 6374	5:51.2 p.m.	76°		
25	6.8	BD —6° 6335	0:51.1 a.m.	115°		
30	6.1	372 B Tauri	9:34.0 p.m.	83°	10:39.5 p.m.	245°

*P is the position angle of the point of contact on the moon's disk measured eastward from the north point.

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SKY-GAZERS EXCHANGE

Classified advertisements are accepted for this column at 30c a line per insertion, 7 words to the line. Minimum ad 3 lines. Remittance must accompany orders. Address Ad Dept., Sky and Telescope, Harvard College Observatory, Cambridge 38, Mass.

FOR SALE: 10" aluminized parabolic mirror, 78" focal length, Pyrex, for $75.00. Please write Leslie Freckman, 4957 N. Mulligan Ave., Chicago 30, Ill.

FOR SALE: 2" telescope (used), made by Harrys & Son, London. Altazimuth mount, on tripod. With one terrestrial eyepiece. Price $65.00. Write J. Milthaller, 1493 Montgomery Ave., New York 53, N. Y.

FOR SALE: 4½" Pike refracting telescope with finder and 5 oculars, 1 terrestrial, 1 diagonal, sun shield, solar screen, tripod with rack steadier. Make offer. William Dewey, 670 Alta Vista Drive, Sierra Madre, Cal.

Because of the death of Theodore E. Jaslerski the following items are for sale: patterns, drawings, grinding and polishing machine, all specially made tools, glass blanks, castings and so forth. Phone evenings or write E. Jaslerski, 3222 N. Hamlin Ave., Chicago 18, Ill. Keystone 5589.

★ ★

PLANETARIUM NOTES

Sky and Telescope is official bulletin of the Hayden Planetarium in New York City and of the Buhl Planetarium in Pittsburgh, Pa.

★ **THE BUHL PLANETARIUM** presents in *November,* WEATHER—SECRET WEAPON NO. 1.

More than most of us realize, the course of the war in all theaters of operation has been largely governed by the weather, and by the meteorologist's knowledge of how to predict the weather before it comes. The Japs used weather as a weapon in the Pearl Harbor attack, as did the Germans in the blitzkrieg campaigns of Poland and France. This sky show tells the story of how the Allied Nations have perfected use of this weather weapon, turning it against the Axis to remarkable advantage and making it global in range. The battles of Midway and the Bismark Sea hinged upon the weather, as did the invasion of Normandy. Also, in this planetarium presentation, visitors discover many dependable weather signs—from various types of clouds to lunar haloes—which they can use for predicting the weather.

★ **THE HAYDEN PLANETARIUM** presents in *November,* COLOR IN THE SKY. (See page 8.)

In *December,* THE CHRISTMAS STAR. During the last month of the year we present the traditional Planetarium version of the story of the Christmas star. Old English carolers, and the songs themselves, stars in the crisp sky, and the Christmas star above all give charm and beauty to the December show. What was the Star of Christmas—comet, planet, meteor, nova, or group of planets?

★ SCHEDULE BUHL PLANETARIUM

Mondays through Saturdays ..... 3 and 8:30 p.m.
Sundays and Holidays ..... 3, 4, and 8:30 p.m.

★ STAFF—*Director,* Arthur L. Draper; *Lecturer,* Nicholas E. Wagman; *Manager,* Frank S. McGary; *Public Relations,* John F. Landis; *Chief Instructor of Navigation,* Fitz-Hugh Marshall, Jr.; *Instructor, School of Navigation,* Edwin Ebbighausen.

★ SCHEDULE HAYDEN PLANETARIUM

Mondays through Fridays ..... 2, 3:30, and 8:30 p.m.
Saturdays ..... 11 a.m., 2, 3, 4, 5, and 8:30 p.m.
Sundays and Holidays ..... 2, 3, 4, 5, and 8:30 p.m.

★ STAFF—*Honorary Curator,* Clyde Fisher; *Associate Curator,* Marian Lockwood; *Assistant Curator,* Robert R. Coles (on leave in Army Air Corps); *Scientific Assistant,* Fred Raiser; *Lecturers,* Charles O. Roth, Jr., Shirley I. Gale, John Saunders.